New Scientist

WEEKLY 24 June 2023

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WHY 2023 IS SET TO BE THE HOTTEST YEAR ON RECORD

LIFE'S MAGIC NUMBER

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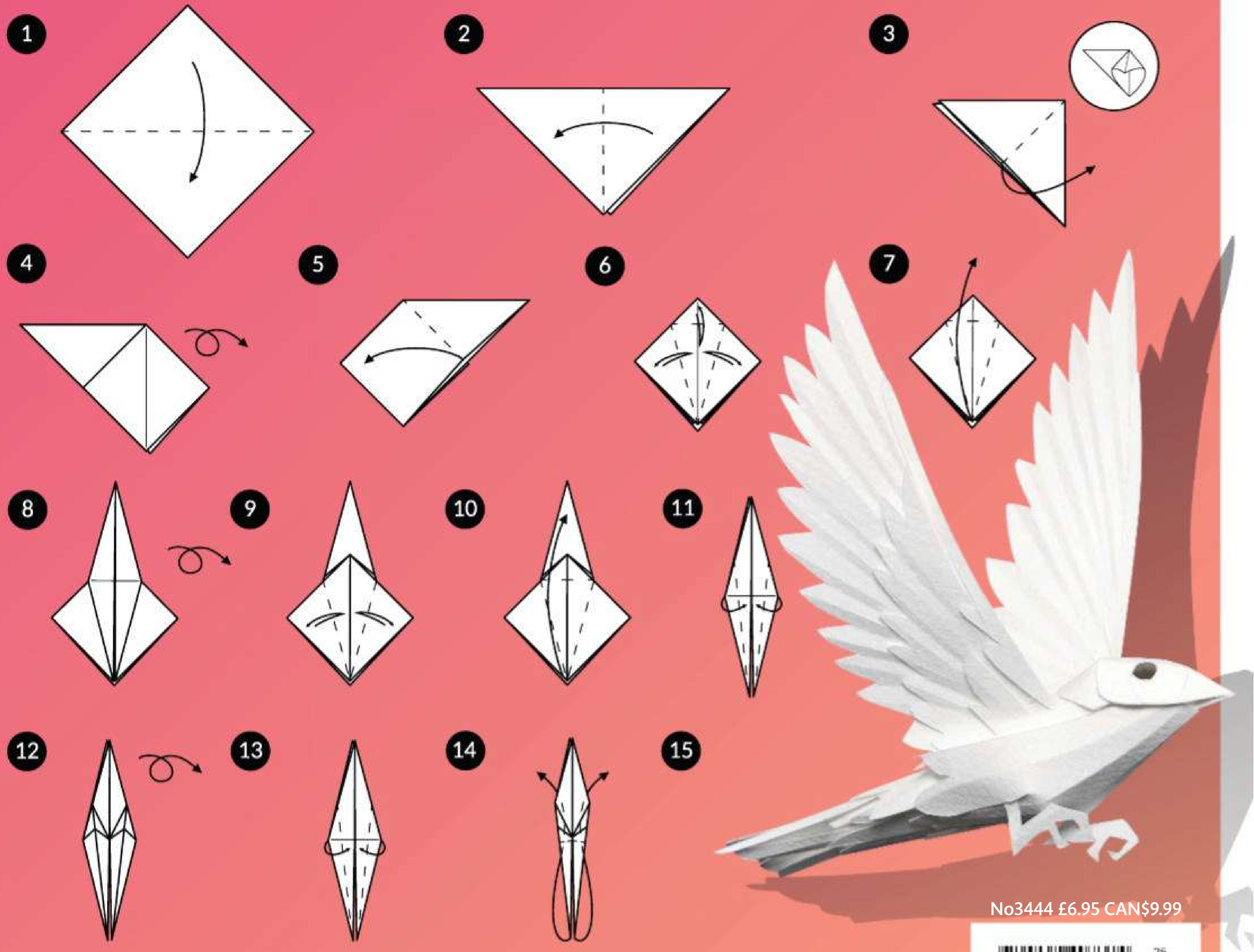

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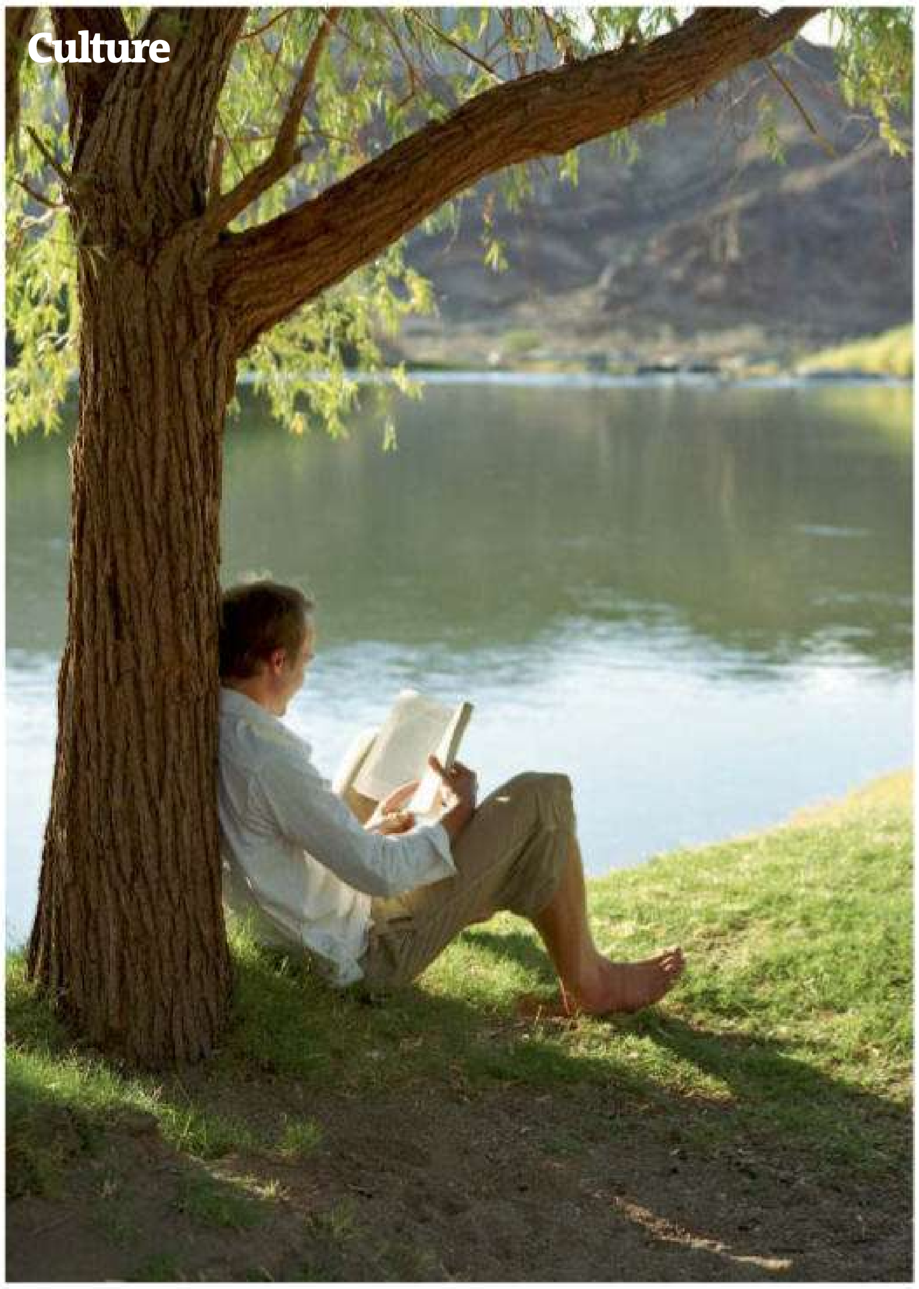
Culture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Elsewhere on New Scientist

Virtual event

Ageless: How science can help us live longer and better

What if we could reverse ageing to prevent conditions including Alzheimer's? Join computational biologist Andrew Steele to explore the efforts to do just that, and pick up some tips on how to slow down the ageing process in your body. Watch this free subscriber-only event online at 6pm BST/ 1pm EDT on 22 August.

newscientist.com/benefits

Tour

Total solar eclipse 2024: Houston to San Antonio

Experience one of nature's most magnificent events at an exclusive viewing location in Texas. Joined by renowned astronomer John Mason and *New Scientist* features editor Abigail Beall, you will visit several astronomical sites including NASA's Space Center Houston and two observatories. The eight-day tour begins on 3 April 2024 and tickets cost £4399.

newscientist.com/tours

Podcast

Weekly

The team discusses how our gut microbiome might influence our intelligence. There is also news of cephalopods that can edit their own genetic material to survive environmental changes. Plus, in a bonus episode, comment and culture editor Alison Flood talks to author Lewis Dartnell about how our biology has shaped history.

newscientist.com/nspod

MARTIJN BEEKMAN/AFP VIA GETTY IMAGES

Hidden secrets Scans reveal new details in Vermeer's masterpiece

MARK CONLIN/VWPICS/ALAMY

Survival tactic Cephalopods can edit their own genetic material

Video

Art history

On our YouTube channel this week, there is an interview with painting conservator Abbie Vandivere and microscope specialist Emilien Leonhardt about a new exhibition at the Mauritshuis Museum in the Netherlands. By scanning Johannes Vermeer's *Girl with a Pearl Earring*, researchers have revealed many hidden details, including that the girl originally had eyelashes.

youtube.com/newscientist

Newsletter

Our Human Story

South America was the last continent settled by humans, but we are learning that early inhabitants were as artistic and creative as other populations, writes Michael Marshall. For instance, we have found that a writing system was in use in the region that is now Peru more than 1000 years ago.

newscientist.com/our-human-story

Newsletter

> **"We thought South America had no ancient writing systems. That is now changing"**

Essential guide

Our planet still holds many secrets. How did Earth form? How is it changing with global warming? And are there other Earth-like worlds out there? This *New Scientist Essential Guide* offers answers. Available to download in the *New Scientist* app or to purchase in print from our shop.

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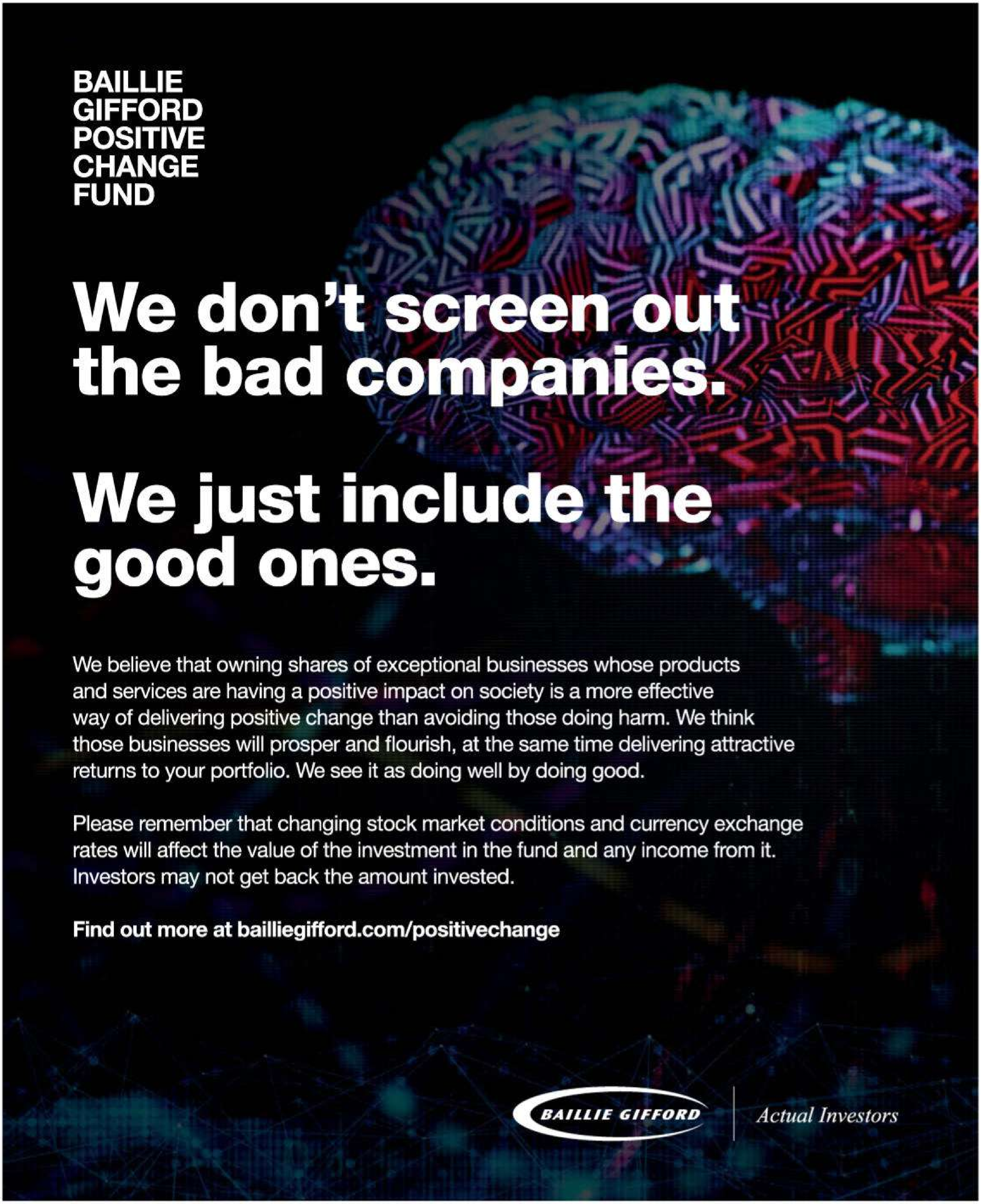

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Net-zero action

The biggest buzzword in climate action is being used as a cop-out

BURNING fossil fuels releases carbon dioxide into Earth's atmosphere. As the levels of CO_2 in the atmosphere increase, so too do global temperatures. Beyond a given temperature limit, life on Earth becomes impossible. Stop us if you have heard this one before.

The basic science of climate change is so universally accepted that only the most fringe elements of society now deny it. Instead, there is a new group of people holding back climate action – delayers, not deniers – that have been enabled by two simple words: net zero.

The science of net zero is also well accepted. Since releasing CO_2 increases global temperatures, we must stop doing so. Until we are removing as much carbon from the atmosphere as we put in – the "net" in net zero – temperatures will rise. Many countries and companies have pledged to hit this goal by 2050.

But we cannot simply slam on the brakes at the last moment. If our carbon emissions remain net positive until 2049, hitting zero only in 2050, we will blow it.

> "For executives with an eye on the next financial quarter, net zero offers clear appeal"

Despite this, Shell announced last week that it plans to grow its natural gas business while committing to an earlier pledge to reach net zero by 2050, following a similar announcement by BP earlier this year (see page 18). This, in the opinion of one researcher who spoke to *New Scientist*, appeared "scientifically incoherent".

The broader issue is that the "net" in net zero offers a tantalising cop-out. It was intended to acknowledge that some sectors will be near impossible to fully decarbonise, and must be offset. Instead, it has become the carbon equivalent of a tax wheeze. If we balance the books with carbon offsets, the thinking goes, emissions can continue to rise. Better still, if we release carbon today, we can remove it later, with technology that doesn't yet exist at scale. For executives or politicians with an eye on the next financial quarter or electoral cycle, net zero has clear appeal.

But the atmosphere doesn't work like that. As we face possibly the warmest year on record (see page 8), it is time to go back to basics. Cut emissions. Now. Fast. ▮

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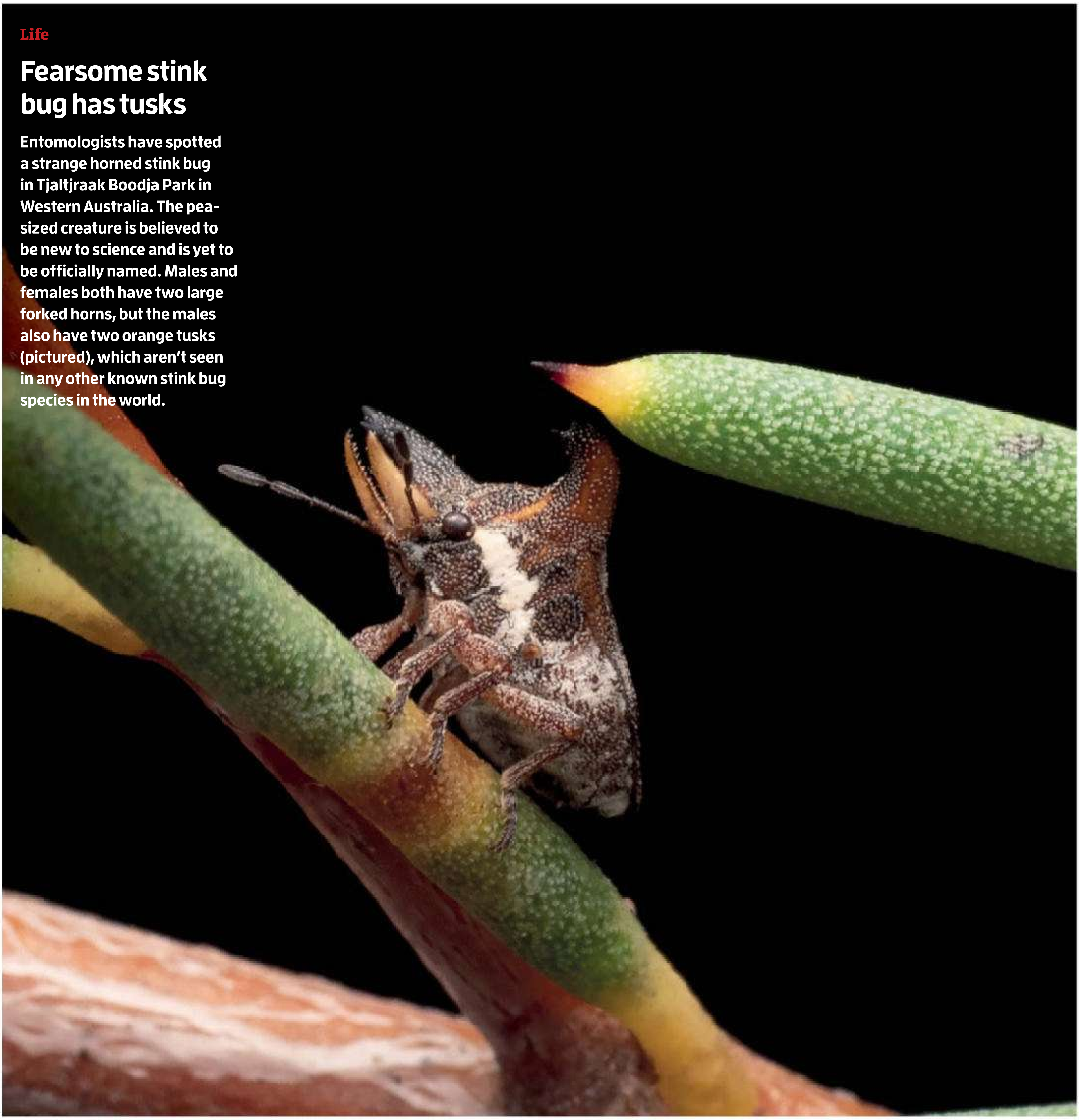
Extinct lizard was a supersized, armoured skink p19

Life

Fearsome stink bug has tusks

Entomologists have spotted a strange horned stink bug in Tjaltjraak Boodja Park in Western Australia. The pea-sized creature is believed to be new to science and is yet to be officially named. Males and females both have two large forked horns, but the males also have two orange tusks (pictured), which aren't seen in any other known stink bug species in the world.



PARKS AUSTRALIA

Analysis Climate

Why 2023 is shaping up to be the hottest year on record

Global weather phenomena are conspiring to raise temperatures further this year, adding to human-driven climate change, finds **Madeleine Cuff**

SALMAN ALI/HINDUSTAN TIMES VIA GETTY IMAGES

Workers filling water bottles during a heatwave in June in New Delhi, India

SPIKING temperatures in the world's oceans and the arrival of El Niño weather conditions in the Pacific mean that 2023 is shaping up to be the hottest year on record, with researchers saying the planet is entering "uncharted territory".

The hottest year on record is 2016, which is also when the world was last in a warming El Niño weather pattern (although other agencies say 2020 also tied for the top spot). Now, temperature records this month suggest 2023 could be tracking close to 2016. The first 11 days of June registered the highest global temperatures on record for this time of the year, according to Copernicus, the European Union's Earth observation programme, following on from the second-warmest May on record and the fourth-warmest April.

The peak occurred on 9 June, when the average global air temperature was 16.7°C (62°F), just 0.1°C below the warmest ever recorded on 13 August 2016.

While human-driven climate change continues to raise global temperatures, there is no evidence to suggest that the process is accelerating this year. Instead, specific warming conditions are being layered on top of the 1.3°C temperature rise caused by climate change so far, pushing records ever higher.

One of the drivers of the recent heat surge has been the warmth in and above the oceans. For months, scientists have been warning that sea surface temperatures have been at record highs, driven by marine heatwaves around the world. In the North Atlantic on 17 June, temperatures peaked at 23°C (73.4°F), 0.2°C above the previous high set in 2010.

It isn't yet clear why the oceans are so hot now, particularly given that El Niño conditions, which drive warmer sea temperatures, have only just arrived and won't peak until the end of the year.

Weakened trade winds as a result of changes in atmospheric dynamics is perhaps the most likely explanation, says Samantha Burgess at Copernicus. In the North Atlantic, a slump in wind strength may have reduced the amount of dust blowing through this part of the ocean from the Sahara, which usually has a cooling impact.

2016

The hottest year on record so far

16.8°C

Warmest average global air temperature (62°F), seen on 13 August 2016

16.7°C

Average global air temperature recorded on 9 June 2023

The surge in ocean and air temperatures is surprising for the time of year, says Burgess. Globally speaking, the first few days of June breached a 1.5°C increase in temperatures compared with the same time of the year in pre-industrial times – a threshold only previously surpassed during northern hemisphere winters, when temperature anomalies are more common.

"What we've observed to date is suggesting that 2023 will be probably in the top five warmest years," says Burgess. "We are in uncharted territory. No one in human history has ever seen ocean temperatures this warm, and the air temperatures that we're seeing as well are coming up to record-breaking."

Although the broad drivers of warming – El Niño conditions plus climate change – are the same as in 2016, this year the heat is manifesting differently. Whereas in 2016 spikes in temperature were concentrated over the Siberian Arctic, in 2023 the warmth has been seen in multiple spots, including in the Southern Ocean and Antarctica earlier this year.

Over recent months, there has been growing concern over the lack of Antarctic sea ice, with February 2023 setting a new all-time record for minimum sea ice of just 1.79 million square kilometres. The ice is reforming as winter takes hold there, but is still tracking well below average.

This atmospheric variability, with El Niño on top of general warming, is the same as it was seven years ago, says Christopher Merchant at the University of Reading, UK. "There is a good chance that we're heading for another record-breaking year, this year or next year."

As El Niño builds, scientists expect to see more temperature anomalies as its influence starts to tilt weather patterns. "On top of the world as a whole being slightly warmer, you tend to get regional weather patterns, which gives you climate anomalies," says Manoj Joshi at the University of East Anglia in Norwich, UK.

The way the warmth manifests won't be the same as in 2016, says Merchant. "I think there are unlikely to be parallels in the exact patterns of warm ocean temperatures or land temperatures, because the climate doesn't really repeat like that." ▮

Artificial intelligence

AIs will become useless if they keep learning from other AIs

Alex Wilkins

TRAINING artificial intelligences using text and images from other AIs, which have also been trained on AI outputs, may eventually make them functionally useless.

AIs such as ChatGPT, known as large language models (LLMs), use vast repositories of human-written text from the internet to create a statistical model of human language. This allows them to predict which words are most likely to come next in a sentence. Since LLMs have been available, the internet has become awash with AI-generated text, but the effect this will have on future AIs is unclear.

Ilia Shumailov at the University of Oxford and his colleagues simulated how AI models would develop if they were trained using the outputs of other AIs. They found that the models would become heavily biased, overly simplistic and disconnected from reality – a problem they call model collapse.

The study suggests this failure happens because of the way that AI models statistically represent text. An AI that sees a phrase or sentence many times will be likely to repeat this phrase in an output, and less likely to produce something it has rarely seen. When new models are then trained on text from other AIs, they see only a small fraction of the original AI's possible outputs. This subset is unlikely to contain rarer outputs and so the new AI won't factor them into its own possible outputs.

The model also has no way of telling whether the AI-generated text it sees corresponds to reality, which could introduce even more misinformation than current models, the study found (arXiv, doi.org/kfpw).

A lack of sufficiently diverse training data may be compounded by deficiencies in the models themselves and the way they are trained, which don't always perfectly represent the underlying data in the first place. Shumailov and his team showed that this results in model collapse for a variety of different AI models.

> "Ultimately we are converging into this state of madness where it's just errors, errors and errors"

"As this process is repeating, ultimately we are converging into this state of madness where it's just errors, errors and errors, and the magnitude of errors are much higher than anything else," says Shumailov.

How quickly this process happens depends on the amount of AI-generated content in an AI's training data and what kind of model it uses, but all models exposed to AI data do collapse eventually, the team found.

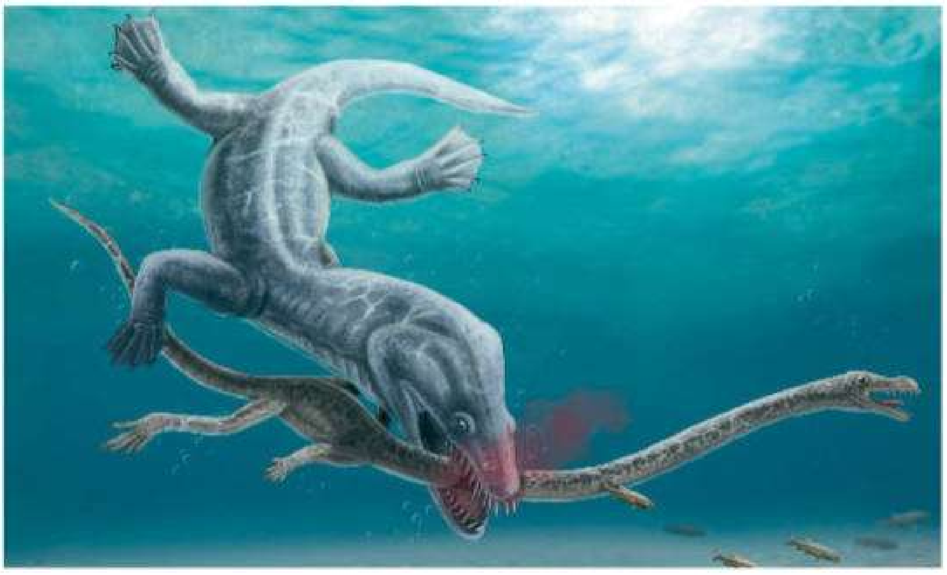
The only way to get around this would be to label and exclude the AI-generated outputs, says Shumailov. But this is impossible to do reliably, unless you own an interface where humans enter text, such as Google search or OpenAI's ChatGPT – a dynamic that could entrench the financial and computational advantages of big tech companies.

Some of the errors might be mitigated by instructing AIs to give preference to training data from before AI content flooded the web, says Vinu Sadasivan at the University of Maryland.

It is also possible that humans will edit AI content before posting it to the internet, says Florian Tramèr at the Swiss Federal Institute of Technology in Zurich, which might lessen the problem. ■

Palaeontology

Ancient reptiles' long necks increased risk of decapitation



ROC OLIVÉ (ICP MIQUEL CRUSAFONT)/FECYT

Tanystropheus hydroides being attacked underwater by a predator

FOSSILS of two Triassic reptiles show severed heads and necks with bite marks, highlighting a drawback of the very long necks common to many ancient sea creatures.

"We provide the first tangible proof that this body plan was, at least in some animals, a weak spot," says Eudald Mujal at the Stuttgart State Museum of Natural History in Germany.

He and his colleague Stephan Spiekman, also at the museum, used high-resolution photography and 3D modelling to assess the fossils of two species, *Tanystropheus hydroides* and *Tanystropheus longobardicus*, on display at the University of Zurich, Switzerland.

The 242-million-year-old specimens included two complete skulls and two abruptly shortened spines. One animal had only 10 of its 13 neck vertebrae, and the other only seven. Both necks had multiple bite marks, including one that showed the telltale signs of a break caused by a violent impact, say the researchers (*Current Biology*, DOI: 10.1016/j.cub.2023.04.027).

The fossils reveal that a predator attacked from behind and above, crushing and severing the neck. The bites were so far behind the head that the animals probably didn't see their attackers coming, says Mujal.

The purpose of the up-to-2-metre-long neck is unclear, but Spiekman says it may have enabled *Tanystropheus* to catch fish while keeping its body less visible on the sea floor. "We think it just sat there and waited for its prey to come to it – which is something modern crocodilians do as well," he says.

The long-necked body plan was "very, very successful" despite the risk of decapitation, says Mujal. It lasted 175 million years, occurring throughout this ancient world. ■

Christa Lesté-Lasserre

Technology

Cryptocurrencies go quantum

Using quantum computers to mine cryptocurrencies like bitcoin could slash their huge electricity use, finds **Alex Wilkins**

QUANTUM computers could be used to mine existing cryptocurrencies like bitcoin or future, more energy-efficient ones, slashing their electricity use, according to two new analyses.

Cryptocurrencies that rely on a "proof of work" method perform computationally intensive calculations to produce new coins and certify transactions, at great energy cost. Some networks have moved to less power-hungry techniques, like Ethereum's "proof of stake", but bitcoin, the world's largest cryptocurrency, still runs on proof of work and consumes 0.5 per cent of electricity globally.

Now, two proposals suggest that quantum computers might be able to help cut this energy use.

Adapting cryptocurrency schemes to run on quantum computers is tricky, says Gavin Brennen at Macquarie University in Sydney, Australia, because the computational speed-up offered by such machines can make it too easy to solve the problems that networks like bitcoin rely on to prove work has been done. "This really changes the dynamics of the network," says Brennen. "So, we were looking for a way to use quantum devices and be faster and more energy efficient, but that wouldn't distort the consensus dynamics too much." Such distortion could affect the value of the cryptocurrency.

> "The first person to figure out how to make quantum crypto-miners will have a tremendous advantage"

Brennen and his team have proposed using a kind of quantum computer called a boson sampler to create a new cryptocurrency network, which should be a more energy-efficient alternative when run on quantum hardware.

AKOS STILLER/BLOOMBERG VIA GETTY IMAGES

The Evobits "farm" in Romania mines the Ethereum and Zilliqa cryptocurrencies

For two people on the network to agree on something, which is required to certify transactions or mine currency, they both must prove they have performed true boson sampling, which involves measuring a sample of photons that have passed through a labyrinth of mirrors and beam splitters. Classical computers can't accurately make these measurements above a certain number of photons.

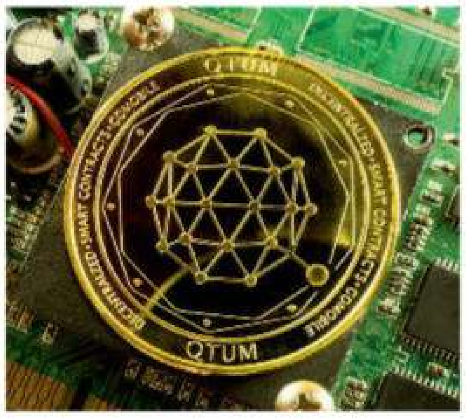
To allow the scheme to work, Brennen and his team had to modify traditional boson sampling by making the photon measurements less exact, because the chance of two people getting the same combination of measurements was so improbable. This is needed so people can verify a solution. By placing the values of the measured photons in ranges, it becomes more likely that two quantum miners will get the same result, says Brennen.

The approach is theoretical, but Brennen and his team are working on a real-world implementation of the scheme on quantum devices (arXiv, doi.org/kftb).

If quantum computers come to threaten the encryption that cryptocurrencies rely on to be secure, this method could be a useful alternative and save energy too, says Mark Webber at UK start-up firm Universal Quantum.

Machines capable of boson sampling don't need to be full-blown quantum computers, but could still cost thousands of pounds, which might deter bitcoin miners from migrating, says Carlos Perez-Delgado at the University of Kent, UK. Instead, he and his colleague Joseph Kearney, also at the University of Kent, have come up with an alternative.

The qtum cryptocurrency isn't actually quantum, but one day it could be



ROMAN OPLEV/ALAMY

The pair analysed how much energy might be saved if we used quantum computers to mine cryptocurrencies. They found potential annual savings of almost 127 terawatt-hours, about 90 per cent of bitcoin's estimated energy consumption, or equivalent to Sweden's annual energy budget.

To do this, they compared the energy cost of a commonly used bitcoin mining processor with the estimated cost of using three different quantum computers. Two were hypothetical machines that can correct errors to varying degrees and one was a current, error-prone device – these are known as noisy intermediate-scale quantum (NISQ) computers. They ran a form of what is called Grover's algorithm to do the mining (arXiv, doi.org/kftc).

"It is a matter of when, not if, NISQ bitcoin miners will be used," says Perez-Delgado. "The first person, company or entity to figure out how to cost-effectively develop custom-built NISQ crypto-miners will have a tremendous mining advantage."

It is interesting to do these energy estimates, says Webber, but it is unclear whether this form of Grover's algorithm might work on all quantum machines.

He would also like to know if future, fully error-corrected quantum machines would take longer to perform computations – due to time that would need to be devoted to checking errors – and thus use more energy than has been factored in here. Another issue is whether the intense cooling required to keep future quantum computers functioning might make their energy use higher than expected, he says. ■

Earth

Humans pumping groundwater has shifted Earth's axis

James Dinneen

OVER about two decades, humans pumped enough water out of the ground that we shifted Earth's poles by almost a metre. This is equivalent to the polar drift caused by melting Greenland ice over the same period.

Clark Wilson at the University of Texas at Austin and his colleagues have modelled how changes in the distribution of water around the planet have affected the drifting of the poles. Some of that wandering is down to natural causes. Because Earth isn't a perfect sphere, it wobbles like a top several metres each year. The poles also drift due to changes in the distribution of mass around the planet, such as the seasonal movement of water.

"There are a number of things contributing to polar drift, and they all add up," says Wilson. Filling reservoirs and pumping groundwater both play a part, as well as climate change melting glaciers and the resulting sea level rise, although it wasn't clear how big the effect of each might be.

Wilson and his team modelled the drift using estimates of the amount of groundwater pumped between 1993 and 2010 (around 2100 gigatonnes) and the associated rise in sea level, which they estimated at 0.3 millimetres per year.

The polar drift attributed to this amounted to about 80 centimetres (*Geophysical Research Letters*, doi.org/gscsrk). Wilson says this is especially due to large aquifers located at mid-latitudes, which have the greatest effect on polar drift. This doesn't have consequences in terms of the length of the day or of the seasons, although knowing Earth's precise axis is essential for GPS technology to work, says Wilson.

"The precise number doesn't matter really," says Manoochehr Shirzaei at Virginia Tech. "What matters is that the volume is so gigantic that it can impact the polar drift of the Earth."

Animal behaviour

Chimpanzees can prepare for alternative futures

Chen Ly

WE ARE no longer the only animal known to think ahead and prepare for two possible futures – chimps can do it too.

If you are unsure whether it will be sunny or raining later, you might grab sunscreen and an umbrella before you leave home. This ability to consider different eventualities, known as modal reasoning, is essential to human cognition.

It was thought that other animals couldn't manage the feat, including our closest living relatives, chimpanzees. This is in part because a 2017 study found that the primates lack the capacity to prepare for mutually exclusive outcomes.

The results weren't accepted by all, though, because the study expected the chimpanzees to use behaviours that don't come naturally to them, says Jan Engelmann at the University of California, Berkeley.

"To demonstrate competence, they had to cover both exits of a Y-shaped tube with the palms of their hands," he says. "I've worked for 12 years with chimpanzees now, and I've never seen them show this behaviour."

Now, Engelmann and his colleagues have tried an alternative method relying on behaviour that comes more naturally to the animals.

Working at Ngamba Island Chimpanzee Sanctuary in Uganda, where the animals can roam in 95 acres of forest, the researchers put individual chimps in front of two tilting platforms, each with a piece of food on it. The first version of the experiment used an opaque cylindrical tube above one of the platforms, through which the team would drop a rock.

"The representation of alternative possibilities is fundamental to creativity and morality"

If the chimpanzee didn't intervene, the food would fall, but if it stabilised the platform with its hands, it was given the food as a reward. In this scenario, the 15 chimpanzees only stabilised the platform they knew the rock would hit.

The second experiment used an opaque inverted Y-shaped tube with an exit above each platform. Not knowing which platform the rock was going to hit meant the chimpanzees behaved differently. Thirteen of the 15 were more likely to cover their bases and steady both platforms to protect both pieces of food (*Biology Letters*, DOI: 10.1098/rsbl.2023.0179).

"To my knowledge, they're the first [non-human] animals who demonstrate competence in a task measuring the representation of alternative possibilities," says Engelmann.

Some evidence suggests that children aged between 1 and 2.5 years can consider mutually exclusive outcomes, says team member Mariel Goddu at Harvard University. But there are researchers who argue that these abilities don't develop until the age of 4, when children are able to talk about multiple possibilities. The chimpanzee findings support the earlier age range, showing that this ability may not be dependent on language, she says.

"The representation of alternative possibilities is fundamental to many cognitive capacities that humans are proud of, like creativity and morality," says Engelmann. "It's quite exciting to think that there might be an evolutionary history to this ability as well."

"I am not at all surprised that chimpanzees are capable of modal reasoning, but it is great to see confirmation of these abilities using non-invasive cognitive experiments," says Ammie Kalan at the University of Victoria in Canada. This study shows how taking the time to appreciate chimpanzees' natural behaviour can help us challenge results from studies in captive animals, she says.

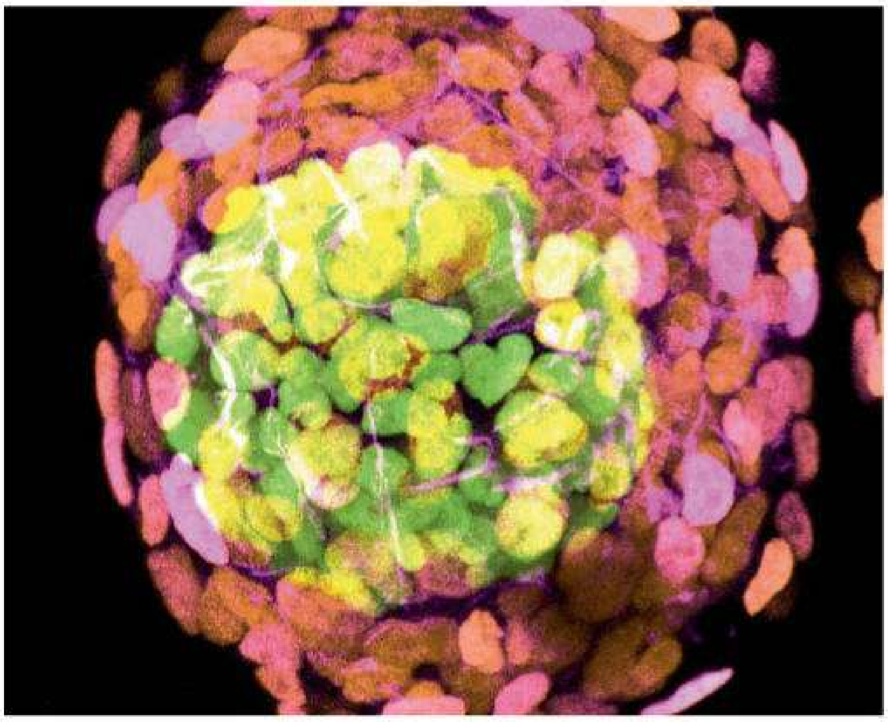
Two chimpanzees that showed their skills on Ngamba Island, Uganda

ESTHER HERRMANN

Briefing

Synthetic embryo breakthrough

Human embryo-like structures have been made from stem cells and reached a landmark stage. **Clare Wilson** explains why it matters



BAILEY WEATHERBEE/ZERNICKA-GOETZ LABORATORY/UNIVERSITY OF CAMBRIDGE

A synthetic embryo developing various cell types, coloured differently

A TEAM has announced the creation of the first human "synthetic embryos" – embryo-like structures made from stem cells – that have been grown to a stage equivalent to just past 14 days old, the legal limit to study natural embryos in the UK.

What are synthetic embryos?

The synthetic embryos are similar to early embryos, a tiny ball of cells arising from a sperm fertilising an egg, but created from stem cells grown in the lab.

The structures aren't wholly synthetic, because the stem cells came from an embryo, and they have some differences to naturally formed embryos. Some prefer to call them stem cell-based embryo models.

What is the big step forward?

Until recently, researchers had made synthetic embryos only from animals such as monkeys. On 14 June, Magdalena Żernicka-Goetz at the University of Cambridge announced that her team had grown the human versions to a stage at which a real embryo would implant into the uterus and start developing different tissues, including the precursors of cells that go on to form sperm and eggs.

This is equivalent to a stage between day 7/8 and day 14 in real embryos, says Żernicka-Goetz. She presented the unpublished work at an International Society for Stem Cell Research meeting in Boston.

14 days

Legal limit for studying human embryos in most countries

Why make synthetic embryos?

They can be made in unlimited numbers, whereas spare IVF embryos, which are used in early developmental research, are in short supply. All embryos in a batch made from the same stem cells are almost genetically identical, which is useful for studying their response to different conditions. It is also quicker and easier to genetically modify stem cells grown in a dish to understand the functions of different genes.

Are there any other benefits?

In most countries – including the UK and US – natural embryos studied in a dish must be destroyed after 14 days. These rules don't apply to synthetic embryos, so researchers could study embryo development for longer, to learn about organ development and the causes of early miscarriages. It could one day lead to being able to grow organs in the lab for transplants.

Should we make new rules that apply to synthetic embryos?

These are already being drawn up in the UK, but nothing has been announced elsewhere. In the UK, scientists, such as Żernicka-Goetz, legal experts, patient representatives and ethicists have formed a working group to discuss rules and submitted recommendations to the UK's Human Fertilisation and Embryology Authority.

Policy-makers may consider making a cut-off based on the developmental stage reached rather than a time limit, says James Briscoe at The Francis Crick Institute in London.

What would happen if synthetic embryos were put in a uterus?

We don't know, and to do so in humans is illegal. Animal research suggests implanting synthetic embryos wouldn't lead to offspring. When monkey synthetic embryos were transferred into eight females, pregnancy seemed to begin in three cases, but after a few days they miscarried, it was reported in April. This may be because synthetic embryos aren't identical to natural ones. ▮

Space

A star eating a giant planet has created a hellish inferno

Leah Crane

A PLANET about six times the mass of Jupiter has been in the process of being ripped apart, incinerated and devoured by its star for decades. This "extreme evaporation" process has been predicted, but this is the first instance of astronomers being able to observe the phenomenon.

A star called FU Orionis, which is about 1200 light years away, suddenly got hundreds of times brighter than usual about 85 years ago – and it remains that bright to this day. Sergei Nayakshin at the University of Leicester, UK, and his colleagues built a simulation of the system and found the brightening is probably the result of a large planet getting too close to the star and being gradually eaten.

Past observations have shown that FU Orionis has a disc of extraordinarily hot material around it, shining around 300 times brighter than the sun. But it is far smaller and closer in than the sort of disc we would expect to see around a young star, and its temperature is in the tens of thousands of degrees.

"The disc is about 100 times smaller than the typical disc we see, but it is thousands of times brighter than most systems – it actually outshines the star," says Nayakshin. "To be on this planet in this disc would be worse than being in hell."

If the planet is there, as the researchers say observations show, it is extremely young – around 100,000 years old. It has probably been puffed up to about the size of the sun by the intense heat, making it easier for its outer layers to be peeled off (*Monthly Notices of the Royal Astronomical Society*, doi.org/gsb644).

The researchers calculated that it will take a maximum of about 300 years for the entire planet to be slurped up, although that will depend on whether or not it has a solid, dense core – a long-standing mystery about gas giants. ▮

Physics

Record-breaking superconductivity

Scandium can turn into a superconductor at a higher temperature than any other element

Karmela Padavic-Callaghan

THE metal scandium can be made into a superconductor without having to be mixed with other substances, and this occurs at higher temperatures than for any other element. The process still requires extreme cold and pressure, but the discovery may help us make better electronics.

Superconductors – materials that conduct electricity without the electrical resistance that leads to wasted energy – could enable perfectly efficient electronics. But the first superconductors only worked at very low temperatures, so all devices using them had to be kept in powerful fridges.

More recently, researchers have found that the superconducting properties of some materials can be turned on at higher temperatures by changing the materials' chemical composition or putting them under pressure. There is still no definitive consensus on how to make a material that superconducts at room temperature, but all claims about it so far, many of which have been controversial, involve extreme pressure.

Now, two research teams have independently found that when it comes to putting pressure on materials made of only one element, scandium superconducts at the highest temperature yet.

"Solids made of a single element are some of the simplest and cleanest systems for studying superconductivity, but so far they all seemed to have critical temperatures below -243°C," says Jianjun Ying at the University of Science and Technology of China, who worked on one of the experiments. The other research team was led by Changqing Jin at the Chinese Academy of Sciences.

Scandium becomes a superconductor when it is compressed

PHIL DEGGINGER/ALAMY

In both studies, researchers compressed a piece of scandium between two diamonds. Doing this changes the arrangement of the element's atoms, and at high pressures, this deformation allows some electrons to more readily participate in superconductivity.

Both teams repeated the process at different temperatures and pressures, measuring the scandium's electrical resistance. In one experiment, the highest pressure was about 75 per cent of the pressure at the centre of Earth. When the scandium's resistivity dropped to zero, meaning electricity could flow through it without energy loss, they knew it had become superconducting.

For Ying's team, this happened at a pressure of 260 gigapascals and -237°C, while Jin and his colleagues found the highest critical temperature to be -242°C, at 283 gigapascals of pressure (arXiv, doi.org/kfkq and doi.org/kfkr). Accounting for differences in the equipment that the teams used, the two measurements are essentially equivalent, says Jin.

"When I was first starting out as a physicist, [superconductivity at] these temperatures would have been unthinkable for a pure element," says M. Brian Maple at the University of California, San Diego. He says understanding how deforming the material's structure changes its critical temperature could help researchers engineer new superconductors. ▮

Technology

Fuel cell recycles plastic waste and carbon dioxide

A SOLAR-POWERED device could remove carbon dioxide from the air and convert plastic waste into fuel and useful chemicals, in a double boost to recycling.

Previous research on solar fuel cells, which use sunlight to drive chemical reactions that produce fuels, have used pure CO_2. Now, Erwin Reisner at the University of Cambridge and his colleagues have developed a device that utilises CO_2 from industrial processes or from the air, filtering out other gases.

"There has been a tremendous advance in developing carbon capture and sequestration technologies. In parallel, there's been a lot of development in solar fuels devices," says Reisner. "This is the first time combining the two."

The prototype device is split into two compartments. One filters air through an alkaline solution that catches CO_2 and converts it into syngas, a fuel usually used to make ammonia or methanol. In the other, a solution derived from PET plastic waste gets converted into glycolic acid, a chemical used in cosmetics.

The pair work together. For CO_2 to transform into syngas, it needs to gain electrons. Typically, this is done by breaking up water molecules, but that is energy-intensive, says Reisner. Instead, the two compartments act like a battery, with the CO_2 side as the cathode and the plastic side as the anode, transferring electrons between them (*Joule*, doi.org/gscwcj).

"The process is completely circular. We capture CO_2. We make a fuel. You use it. You form the CO_2 again"

The researchers hope the technology will help eradicate new fossil fuel use. "The process is completely circular," says Reisner. "We capture CO_2. We make a fuel. You use it. You form the CO_2 again."

Reisner says it shows there is an alternative to just capturing and storing CO_2. "You can actually make useful products from it."

"It is a nice chemistry," says Jotheeswari Kothandaraman at Pacific Northwest National Laboratory in Washington state, but she would like to know how economically feasible it is. ▮

Chen Ly

Childbirth

Vaginal fluid swab benefits babies

Transferring a mother's bacteria to a newborn can change its microbiome and health

Soumya Sagar

SWABBING newborns delivered via Caesarean section with vaginal bacteria appears to benefit their early development. The finding is based on a small study, so more research is needed before this practice would be recommended.

The early gut microbiome of babies born vaginally tends to be rich in bacteria from their mothers' vaginas, while that of those born via C-section is often dominated by bacteria from their mothers' skin, the environment and possibly breast milk.

So-called vaginal seeding – exposing newborns delivered via C-section to their mothers' vaginal fluid – has been linked to these newborns developing a similar gut microbiome to those born vaginally. However, the safety of the practice and whether it has any positive effect is unclear.

To learn more, Jose Clemente at the Icahn School of Medicine at Mount Sinai in New York and his colleagues looked at 68 pregnant women scheduled to have a C-section. Two hours before the procedure, they put a folded, sterile gauze moistened with saline into the women's vaginas until around 30 minutes before the surgery.

After the babies were born, 32 had the gauze rubbed on their face, chest, limbs, genitals, anus and back, while 36 were rubbed in those areas with a gauze soaked in saline. The researchers also looked at 33 pregnant women who delivered their babies vaginally, which weren't rubbed with gauze.

The parents completed a questionnaire to gauge their child's neurodevelopment – assessing their ability to make sounds and crawl, for example – at 3 and 6 months. Faecal samples were also collected several times up to 6 weeks of age.

At both 3 and 6 months, the C-section babies exposed to the vaginally soaked gauze scored better on the questionnaire than those exposed to the saline gauze. Their scores were also comparable to the babies delivered vaginally.

Faecal samples collected at 6 weeks showed that the gut microbiomes of the babies in the vaginal gauze group were richer in bacteria commonly found in the vagina than those in the saline group. Their overall bacterial make-up was also more mature than the latter group's and on a par with those delivered vaginally (*Cell Host & Microbe*, doi.org/kfj6). No safety issues were reported.

CULTURA CREATIVE RF/ALAMY

The method by which babies are born can affect the make-up of their gut bacteria

"We show that this procedure not only changes the microbiome of C-section infants, but it also modifies a health outcome," says Clemente.

Population studies hint that conditions such as ADHD are more common in people who are born via C-section, so further work could look at whether vaginal seeding affects this.

The study shows the safety of vaginal seeding and that neurodevelopment in babies born by C-section can be altered, says Maria Dominguez Bello at Rutgers University, New Jersey. However, parental reporting of a child's development may be less accurate than assessments made via scans, medical examinations or blood tests, she says. ▮

Physiology

Brain activity 'bar codes' may link to specific memories

PATTERNS of brain activity that are linked to specific memories have been discovered in songbirds. These "bar code" patterns may relate to memory recall and could be present in other animals such as humans.

The black-capped chickadee (*Poecile atricapillus*) stores foods like seeds in hiding places to retrieve at a later date. To find out how its brain processes this behaviour, Selmaan Chettih at Columbia University in New York and his colleagues created a set-up with 128 places where chickadees could store and retrieve food. "We built this floor that has rubber flaps that mimic peeling tree bark," says Chettih. "The birds can peel back these flaps and insert seeds inside."

The researchers implanted electrodes into the brains of five chickadees to measure the activity in an area called the hippocampus as the birds explored the site.

Each time the chickadees stored seeds, the researchers saw a distinct pattern of brain activity in their hippocampus. They witnessed the same pattern when the birds went back to retrieve the seeds. The researchers call these patterns of brain activity bar codes.

"Birds may make multiple caches and retrievals at the same location over time, but these events are all represented differently," says Chettih. Even when a bird stores seeds in two sites near each other, it results in completely different bar codes (bioRxiv, doi.org/kfkn).

"Birds may make multiple seed caches at the same location, but the events are represented differently"

He thinks the bar codes occur when the birds recall a memory. We don't know if the same thing happens in humans, but it is plausible, he says.

The findings support an idea called the indexing theory, says Pedro Jacob at the University of Oxford. This suggests that the hippocampus indexes the brain activity that occurs when we form a memory, and the reactivation of this index results in memory recall. Brain recording and imaging studies hint that the human hippocampus also works like this, he says. ▮

Jason Arunn Murugesu

Animal behaviour

Fighting off a robotic rival boosts male flies' mating success

Gary Hartley

MALE fruit flies reared in a lab are more successful at mating after an encounter with a robotic dummy designed to look like a rival male. The finding could boost efforts to control populations of the flies.

The Mediterranean fruit fly (*Ceratitis capitata*) is one of the most destructive fruit pests in the world, found on every continent except Antarctica. There have been attempts to rein it in by releasing large numbers of sterile males reared in labs. The aim is for these males to mate with wild females but produce no offspring, resulting in a population crash. However, mass-rearing conditions in labs can reduce the sterile flies' ability to compete for mates with wild males.

Donato Romano at the Sant'Anna School of Advanced Studies in Pisa, Italy, and his colleagues have now boosted the sexual success of mass-reared *C. capitata* males by provoking territorial behaviour using replica flies.

Male flies were introduced into an arena and allowed to establish territory on discs made from citrus leaves. Then, a 3D-printed, magnetic model fly was moved towards some of the discs to see if it triggered an aggressive response, such as the males striking it with their wings or "boxing" it using their forelegs.

Males that interacted with the fake fly performed longer courtship behaviours and were more successful in mating with females than males that had no contact with it (*Biological Cybernetics*, doi.org/kfkg).

Applying this approach could improve the success of sterile insect programmes, says Romano.

Diana Pérez Staples at the University of Veracruz in Mexico says providing a more natural setting where flies can interact before release may give the same result as using robots, however. ▮

Environment

North American wildfires may be creating clouds over Europe

James Dinneen

SMOKE from wildfires now burning in North America may be seeding the formation of cirrus clouds over Europe. More clouds could affect the amount of solar radiation trapped close to Earth's surface, in a potential new aspect of climate change.

Cirrus clouds are the wispy strands often visible high in the sky. They grow from accumulations of ice crystals in the frigid air near the stratosphere. Whether these ice crystals form depends on the temperature, humidity and the type and amount of particles floating in the air.

Particles like mineral dust blown up from deserts or soot from aeroplane exhaust can provide a nucleus that crystals form around. This also happens with particles containing sulphur from pollution and natural sources.

But until now, researchers didn't think particles from wildfire smoke had an influence. That is because smoke from wildfires generally didn't reach high enough, says Albert Ansmann at the Leibniz Institute for Tropospheric Research in Germany. Lab tests have also shown that particles in fresh wildfire smoke aren't well suited for ice crystals to form around.

In 2017, however, and during a later expedition to the Arctic, Ansmann and his colleagues observed instances in which cirrus clouds appeared to be forming in the same part of the atmosphere as smoke coming from huge fires burning in California and Canada.

> **"If wildfire smoke increases cloud cover, it could be a new climate feedback loop"**

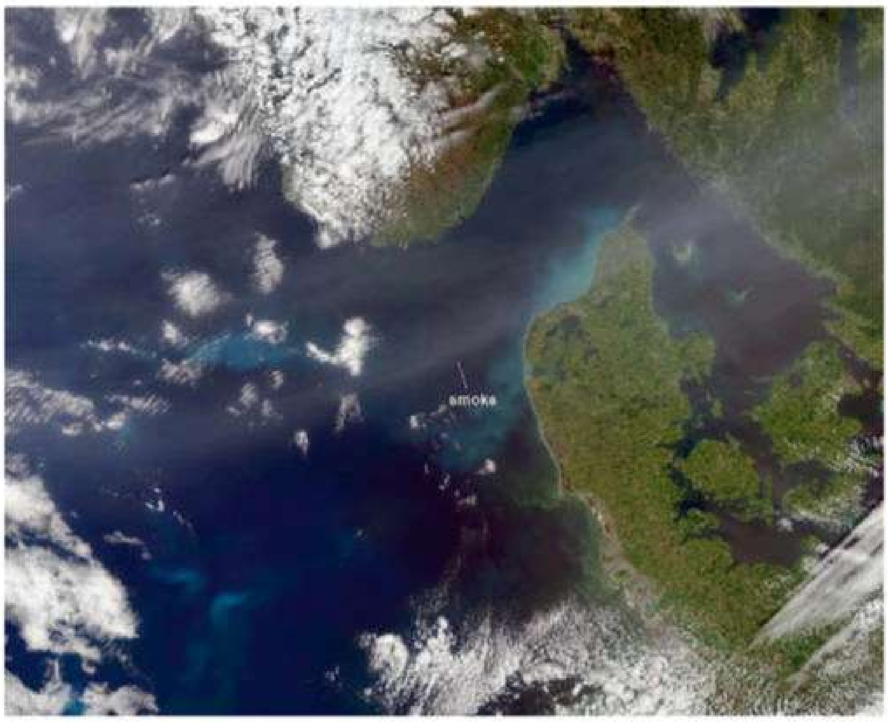
Those observations made Ansmann rethink the link between smoke and clouds, especially with unprecedented megafires sending more smoke higher into the atmosphere. "There's so much smoke close to the stratosphere," says Ansmann. Not only is the air colder at those altitudes, he says, but the smoke particles transform as they waft to those heights. He thinks that over days or months, the smoke particles become spheres, with a core of black carbon soot and a shell of organic carbon, which could make them better suited for nucleating ice particles and seeding clouds.

Ansmann and his colleagues have now observed cirrus clouds forming in conjunction with wildfire smoke in other parts of the world, including in Chile following fires in Australia, as well as in Europe after fires in North America (EGUsphere, doi.org/kfkv). "This is the beginning of a new research field," says Ansmann.

Eric Jensen at the US National Oceanic and Atmospheric Administration isn't convinced. "All they're showing here is a few anecdotes," he says. Until samples of particles in clouds or statistical methods establish a more direct link, he says any relationship is unresolved.

Adeyemi Adebiyi at the University of California, Merced, agrees the evidence is thin so far, but if smoke does influence clouds, he would next want to know how much it happens.

Depending on their thickness, cirrus clouds can reflect or absorb solar radiation and have a cooling or warming influence on the climate. If smoke from wildfires driven by climate change increases cloud cover in ways that add to warming, it could theoretically be a new climate feedback loop, says Adebiyi. Given the growing amount of wildfire smoke in the atmosphere, "this could really be important", he says. ▮



EUROPEAN UNION/COPERNICUS SENTINEL-3 IMAGERY

Satellites saw smoke from Canada's wildfires near Denmark in May

Computing

Quantum computer wins face-off

IBM's Eagle quantum computer has bested a supercomputer at a complex calculation

Karmela Padavic-Callaghan

IN A contest between a quantum computer and a supercomputer attempting the same calculation, IBM's Eagle quantum machine has come out on top.

Quantum computers have sparked excitement for a few decades, but researchers haven't built one that universally outperforms all conventional computers. This is partly because existing quantum computers are "noisy" – their results are corrupted by errors, in the same way that sound can get lost in a crackly recording.

Now, Abhinav Kandala at IBM and his colleagues have shown that even a noisy quantum computer can be more accurate in its calculations than a conventional machine.

They pitched IBM's Eagle quantum computer, which contains 127 quantum bits, or qubits, against a supercomputer at the Lawrence Berkeley National Laboratory in California. Both were tasked with calculating the most likely behaviour of a collection of particles, such as atoms with spin, arranged in a grid and interacting with each other.

The difficulty of this problem increases with the number of particles. For up to a certain number of particles, you can solve the relevant equations on a computer exactly. When larger numbers of particles are involved, supercomputers and approximation methods can handle the calculations, but computations eventually become so complex that conventional computing fails.

The IBM researchers wanted to test Eagle and a set of methods they have developed for mitigating the effects of noise in each of these cases.

When the supercomputer could complete the calculations, the results of the two approaches were in agreement. But when the complexity was increased beyond a certain point, the supercomputer failed, while Eagle was still able to deliver a solution.

Even though there was no way to test if Eagle's final result was correct, Kandala says good agreement with established calculations up to that point gave his team confidence that the quantum computer had passed the test (*Nature*, doi.org/gscgxm).

The IBM researchers don't claim to have achieved quantum supremacy, which would mean proving that Eagle's performance is impossible for any conventional computer and algorithm to match. They didn't test the quantum computer against every existing conventional approach. Kandala says this wasn't their goal because he expects classical computing methods to continue to improve. His team wanted to test the usefulness of the quantum processors available now.

He says the methods used for these calculations could be adapted to a broader set of problems, such as calculating the behaviour of materials or molecules that are of interest in biophysics or chemistry.

"Demonstrating that a device is doing something that absolutely cannot be simulated on a classical computer is notoriously difficult," says Mark Howard at the University of Galway in Ireland. But the competition between quantum and classical computers has historically improved how researchers use both, he says.

"We know classical computing is not going anywhere, but we are excited about getting utility out of our quantum computers," says IBM's Katie Pizzolato, who wasn't part of the team. "The more we use it, the better we will get at making it even more useful."

The hope is that with further development, quantum computers could assist in creating new materials or new compounds for medicines. ▮

Palaeobotany

Ancient plant's leaves didn't follow the golden ratio

A 400-million-year-old fossil reveals that, unlike most modern plants, some of the earliest land plants didn't have leaves radiating out at angles that follow the Fibonacci sequence. The discovery could force a rethink of a century-old theory of leafy plant evolution.

Most modern land plants grow leaves in a spiralling pattern. Their angles in relation to one another settle on the "golden ratio", derived from the Fibonacci sequence – a set of numbers in which each is the sum of the two preceding ones, as in 1, 1, 2, 3, 5 and so on. From flowering artichokes to pine cones, the pattern appears in more than 91 per cent of land plants today.

"Lots of things you're familiar with, if you look at them in detail, you'll actually find evidence of Fibonacci spirals," says Sandy Hetherington at the University of Edinburgh, UK.

To see if the earliest land plants followed this rule, Hetherington and his colleagues examined fossils from the Rhynie chert sediment deposit in Scotland. They chose one of the oldest leafy species preserved: the club moss *Asteroxylon mackiei*, which grew during the Devonian Period, 400 million years ago.

The team digitally layered thin slices of the fossils into a 3D reconstruction. The model revealed no set pattern, but a diverse set of swirls, whorls and spirals (*Science*, doi.org/kfj9).

"I went into this investigation assuming that we were going to find Fibonacci spirals," says Hetherington. "It really came as a shock."

MATT HUMPAGE, NORTHERN ROGUE STUDIOS

Digital reconstruction of the club moss *Asteroxylon mackiei*, which lived 400 million years ago

The unusual structure suggests, contrary to many botanists' assumptions, that leafy plants didn't necessarily start out growing leaves following the Fibonacci pattern. Instead, they appear to have evolved to follow that rule over the past few hundred million years. Some modern club mosses related to *A. mackiei* also have non-Fibonacci spirals, so the trait hasn't been entirely lost.

We don't know why so many plants have leaves that follow the Fibonacci spiral, but some researchers speculate that it is a way of maximising the amount of sunlight that hits each leaf. ▮

Corryn Wetzel

Health

Tiny robot could stop bleeding from inside the body using heat

Karmela Padavic-Callaghan

A SMALL robot that can shape-shift and produce heat could destroy cancer cells or stop internal bleeding. It could also be used to ferry drugs directly to tumours or hard-to-reach places like arteries.

Tiny robots with soft bodies have shown promise for delivering drugs without causing damage, but adding hard elements could make them more useful.

Ren Hao Soon at the Max Planck Institute for Intelligent Systems in Stuttgart, Germany, and his colleagues have designed a centimetre-sized robot to have overlapping aluminium plates inspired by pangolins, the only mammal with scales. They layered rectangular "scales" over magnetic and elastic material, which let the robot change its shape.

The researchers directed magnetic fields at the robot's metal parts to make it move, curl up or stretch out. Changing the frequency of these fields could also heat up the scales, warming the robot's body to more than 70°C.

Soon and his colleagues used the robot's heat to deliver cargo within a model of a stomach. They stuck a piece of rubbery material to the robot to imitate capsules of medicine. The adhesive they used dissolved when the robot warmed up, depositing the cargo. The robot also used the heat to stop bleeding from simulated wounds inside the stomach of a dead pig (*Nature Communications*, DOI: 10.1038/s41467-023-38689-x).

Jake Abbott at the University of Utah says the robot could be used to target tumour cells instead of exposing large amounts of tissue to radiation or chemicals. "You could raise the temperature of the robot above an unsafe level [for normal cells] and hold it in place for a few minutes, and that can kill [cancer] cells. The human body is very sensitive to temperature," he says.

Mind

'Smart drugs' make people worse at problem-solving test

Clare Wilson

PHILIPPE LOPEZ/AFP VIA GETTY IMAGES

Using "smart drugs" for a mental boost may not help with studying

SOME people try to get a mental boost by taking medicines designed to treat ADHD or to counter sleeping disorders, even though they don't have these conditions. But that may not be such a smart move – the drugs worsened the performance of people who didn't have these conditions in a complex problem-solving task.

The drugs include two stimulants: methylphenidate, which is often sold under the brand name Ritalin, and dextroamphetamine. Both are often prescribed to improve concentration and attention in people with ADHD. They are thought to work by raising levels of the brain chemical dopamine, as dopamine-signalling systems may work less well in people with ADHD.

Another drug, called modafinil, is used to help people with fatigue caused by narcolepsy. Modafinil also boosts dopamine signalling.

Use of these drugs by people without these conditions has been growing in colleges and workplaces, for example when cramming for an exam or close to a deadline. People may buy them as "smart drugs" online or from those who have been prescribed them. "It is really rampant among students in US colleges," says Peter Bossaerts at the University of Cambridge.

Previous studies have shown that when people without ADHD take stimulants like these, their performance in memory and concentration tasks is only as good as those taking placebo pills. This suggests that any benefit might stem from the placebo effect.

"It feels like you are working harder, so you may not realise the drugs reduce performance"

Bossaerts and his colleagues wanted to test the drugs in a way that is closer to real-world problem solving. They used an online test called the knapsack problem, in which people have to choose from multiple items of different weights and values to fill a bag, making the total contents as valuable as possible without breaching a weight limit. They can try different combinations before submitting their answer.

The researchers asked 40 people to do multiple versions of the task after taking one of the three drugs or a placebo tablet. The participants visited the lab four times, at weekly intervals, to be tested after each drug and the placebo.

When taking any one of the drugs, people put in more effort, in terms of the number of different options they tried before submitting answers and how long they spent on the task. But their performance was worse, as measured by the total value of items in the bag, compared with taking a placebo (*Science Advances*, doi.org/kfjv).

People would probably think the drugs are helping them, but they aren't, says Bossaerts.

"The medications will keep people awake and increase motivation," says Stephen Faraone at SUNY Upstate Medical University in New York state. You would feel like you are working harder, so you may not realise the drugs reduce performance, he says.

Rachel Fargason at the University of Alabama at Birmingham says it makes sense that stimulants help people with ADHD, but not other people. "You can have too much dopamine – there's an optimum dose," she says.

Ritalin's manufacturer Novartis hadn't replied to requests for comment by the time this article went to press. All three drugs are made by multiple companies.

Analysis Fossil fuels

Shell can't say it backs net zero while betting on oil and gas

Like its rival BP, Shell claims it is committed to reaching net zero by 2050, but this doesn't add up, finds **Madeleine Cuff**

ENERGY company Shell has rowed back on plans to cut its production of fossil fuels, abandoning a target to cut oil production each year for the rest of the decade.

In an investor update on 14 June, Shell said it would maintain its level of oil production at 1.4 million barrels per day through to 2030. It also said it would grow its natural gas business, as part of plans to boost returns for investors. In 2021, it promised to cut its oil output by 1 to 2 per cent a year until 2030.

The announcement comes four months after rival BP scaled back plans to cut the carbon emissions associated with the use of its products, and said it plans to invest in new fossil fuel production.

Both firms say they remain committed to achieving net-zero emissions by 2050, the target adopted by many businesses and governments aiming to give the world a chance of limiting the global average temperature rise to 1.5°C above pre-industrial levels, the goal set in the Paris Agreement.

Increasing fossil fuel production in the short term while targeting net-zero emissions by 2050 is "scientifically incoherent", says James Dyke at the University of Exeter, UK, and threatens global climate targets.

It boils down to the climate maths that underpins the Paris Agreement, says Steve Smith at the University of Oxford. There is a finite amount of additional carbon we can pump into the atmosphere before the 1.5°C goal slips out of reach, he says. According to the Intergovernmental Panel on Climate Change (IPCC), that remaining "carbon budget" was 500 gigatonnes in 2018.

A pilot flame at a Shell oil refinery in Godorf, Germany

REUTERS/WOLFGANG RATTAY

To stay under this limit, the world must cut emissions by 45 per cent by 2030 and reach net-zero emissions by 2050, scientists have calculated. Already the world is behind schedule on the emissions cuts needed. If current rates continue, the 1.5°C carbon budget will be blown by 2032, the UN said in April.

"Any increase in production is completely counter to the science," says Mark Maslin at University College London. "There is no justification for a country, or a company, increasing the production of fossil fuels."

Maslin and Smith say that to demonstrate credibility on climate change, oil and gas firms should halt all investment in new fossil fuel projects, and direct their huge profits into clean-energy technologies. Both the IPCC and the International Energy Agency warn that new oil, gas and coal development is incompatible with limiting warming to 1.5°C.

Shell told *New Scientist* it remains committed to becoming a net-zero business by 2050 and denies it has abandoned its goal to reduce oil output this decade, arguing that it had already met the goal with the sale of an oil project in Texas in 2021, which has reduced Shell's annual output of oil by 21 per cent.

A spokesperson said Shell will invest up to $15 billion by 2025 in low-carbon energy solutions, such as hydrogen fuel and carbon capture, to support its net-zero goal.

BP said in its communications it is supporting an "orderly" transition to net-zero emissions, and is investing £8 billion by 2030 in green technologies, including renewables and electric vehicle charging. ▮

Space

Fastest free-moving star in galaxy caught going 2285 km/s

TWO white dwarfs racing through space are the fastest free-moving stars known and they could explain how some supernovae form.

Type Ia supernovae tend to occur when a white dwarf siphons matter from a neighbouring star and starts to swell, until it eventually becomes massive enough to explode.

But simulations have shown that it is possible for these supernova explosions to occur when two white dwarfs spiral towards each other and collide. White dwarfs are so small and dense that they can orbit each other at close range faster than any other star type, so that when one of a pair explodes, the other is launched away at high speed.

Evidence for supernovae formed this way has proven elusive, but Kareem El-Badry at Harvard University and his colleagues have now used the Gaia star catalogue to identify four white dwarfs travelling fast enough to provide evidence.

They are moving at more than 1000 kilometres per second. "If you find a white dwarf going that fast, it's basically guaranteed that it came from some white dwarf binary where one exploded," says El-Badry. "There's just no other conceivable channel we can think of to make something go that fast."

One of these stars is travelling at 2285 km/s and another at 1694 km/s – the highest velocities for free-moving stars ever recorded, although stars orbiting a black hole have been spotted going faster. All four seem to be made almost entirely of carbon and oxygen, which is another predicted hallmark of stars shot from a supernova, as this process strips away helium and hydrogen (arXiv, doi.org/gsccrk).

> **"If you find a white dwarf going that fast, it came from a white dwarf binary where one exploded"**

In a few hundred million years, the stars will probably leave our galaxy, says El-Badry. Depending on how often supernovae kick out stars, we might even be able to see a white dwarf arriving in the Milky Way. "It's basically the only reasonable prospect we have of observing stars from other galaxies," says El-Badry. ▮

Alex Wilkins

Palaeontology

Extinct lizard was a supersized skink

A GIANT skink with spiky armour and strong jaws roamed Australia until about 47,000 years ago, according to newly found fossils.

Excavations in Wellington caves in New South Wales have unearthed dozens of strange fossils. An analysis led by Kailah Thorn at the Western Australian Museum in Perth has revealed that they all belong to the same extinct species – a skink called *Tiliqua frangens* – that was about 1000 times heavier than typical skinks alive today (*Proceedings of the Royal Society B*, doi.org/gscf73).

Thorn and her colleagues estimate that the extinct skink would have weighed about 2.3 kilograms.

The fossils show that the skink had a deep, broad skull, along with powerful jaws and a coat of thick, spiky armour. **Alice Klein**

Physics

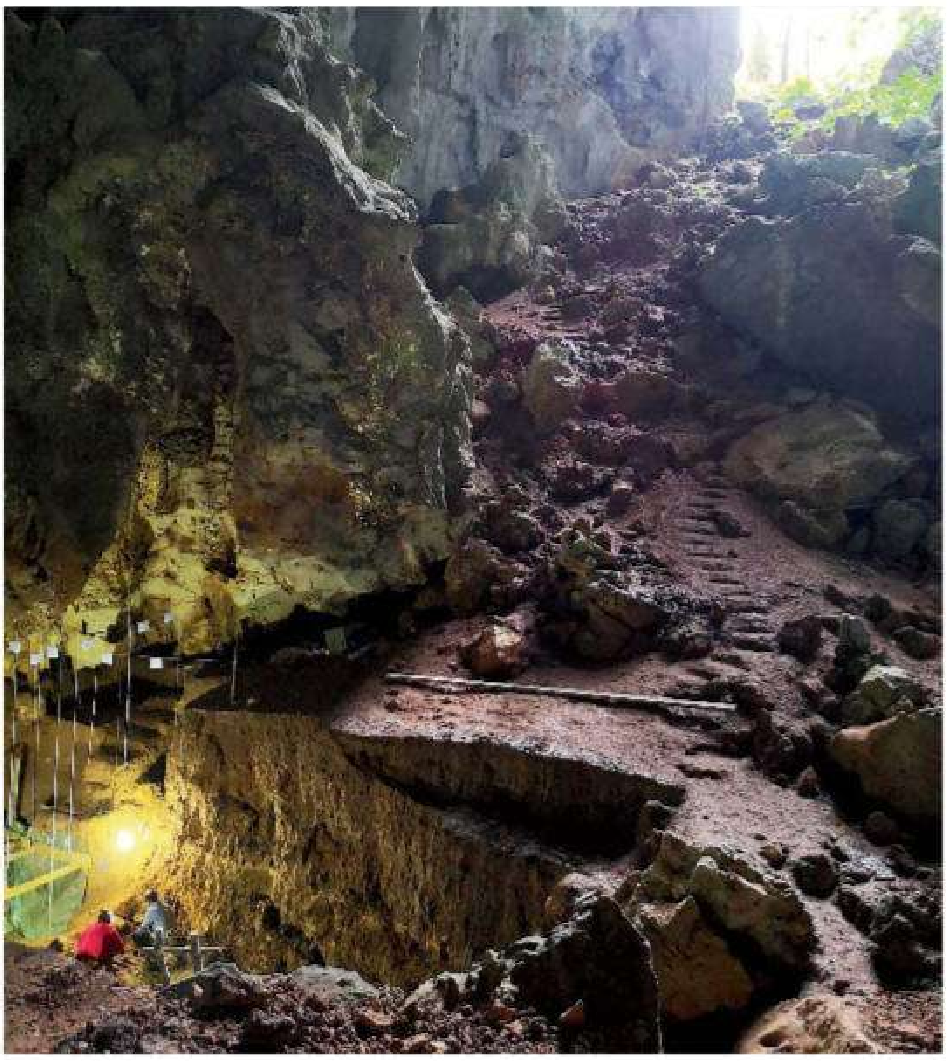
Muons help below-ground navigation

A NAVIGATION system based on high-energy particles created by cosmic rays works underground.

Navigation tools like GPS use radio waves to triangulate a position, but the signals can be disrupted by stone, which is why GPS fails indoors and in tunnels.

To get around this, Hiroyuki Tanaka at the University of Tokyo, Japan, and his colleagues have used particles called muons, which are created when cosmic rays collide with particles in Earth's atmosphere and can pass through materials unaffected.

The researchers have developed a "muometric wireless navigation system", which they used to track a person in a basement with an accuracy of between 2 and 25 metres (*iScience*, doi.org/gscm7d). Such systems could be used for robots or search-and-rescue efforts underground. **Chen Ly**



FABRICE DEMETER

Humans

Cave reveals early evidence of modern humans in Asia

FOSSILS from a Laos cave provide the earliest evidence of modern humans in mainland South-East Asia. Uncovered fragments of bone belonging to *Homo sapiens* may date back 86,000 years, shedding new light on how our species migrated from Africa to Asia.

Since 2009, several modern human fossils – dating to between 46,000 and 70,000 years ago – have been discovered in Tam Pà Ling (pictured above), a cave in north-east Laos. Now, Fabrice Demeter at the University of Copenhagen, Denmark, and his colleagues have added two more fossils to the collection: a small fragment of a human skull and a piece of a human tibia, or shinbone.

Using radioactive isotopes to date the sediment around the fossils, the team estimates the bones are between 68,000 and 86,000 years old. "In mainland South-East Asia, this is the first time we've got such old specimens," says Demeter.

The findings suggest that early modern humans travelled to the region earlier than previously thought (*Nature Communications*, doi.org/kfhz). Prior estimates put this at about 50,000 years ago, with these humans migrating out of Africa and beginning to populate the rest of the world, including Asia. Most people today are descended from these early humans, aside from Indigenous Australians, whose ancestors may have left Africa even earlier.

The fossils discovered in Tam Pà Ling could belong to the ancestors of Indigenous Australians, whose remains found in Australia date back much earlier than 50,000 years ago. But more research is needed to determine this, says Demeter. **CL**

Really brief

SCIENCE PHOTO LIBRARY/ALAMY

Bacteria may cause endometriosis

Endometriosis, in which tissues lining the uterus grow outside it and form painful lesions, may be caused by infections of *Fusobacterium* (pictured above), bacteria that contribute to gum disease. This means antibiotics might prevent or treat the condition (*Science Translational Medicine*, doi.org/gscgw7).

Rays taking over as sharks wiped out

The number of rays is growing in coral reef ecosystems as overfishing obliterates shark populations. The finding comes from a global study that is using underwater cameras to survey the prevalence of sharks and rays at 391 coral reefs in 67 nations (*Science*, doi.org/kfj7).

Beryllium atoms bonded together

A metallic bond between two beryllium atoms has been forged for the first time in the lab. The breakthrough, achieved by using a chemical that can donate electrons to a beryllium compound, could pave the way for the creation of new materials (*Science*, doi.org/kfj8).

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Scan me to book

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Comment

Time to open up

Medical studies of diverse populations benefit humanity as a whole, say **Michal Elovitz**, **Stephen Quake** and **Hannah Valantine**

IN 1958, British surgeon Denis Burkitt was in Uganda studying an obscure form of cancer that appeared to predominantly affect only East African children. Further studies revealed a peculiar pattern of both geography and climate, suggesting it might be caused by a microbe. At the time, the view was that most cancers were caused by exposure to harmful environmental agents. But in 1964, a microbial cause was confirmed with the discovery of the first human "oncovirus" in a tissue sample from an African individual. It soon became clear that this virus, now called Epstein-Barr virus, and other infectious agents are important causes of cancer, transforming our ideas about the disease.

Had Burkitt not worked with people in Africa, this might have taken longer to come to light. Studies of racially and ethnically diverse populations are the best way to reveal disproportionate disease risk and burden in specific groups, and they also benefit humanity as a whole.

We in science and medicine aren't immune to the biases and prejudices that lead to discrimination. To improve health for all, we must acknowledge how inequities continue to shape our professions and take concrete steps to put science on a fairer and more productive path.

The historical abuse of research in traditionally underrepresented populations – such as the unethical Tuskegee syphilis study, in which Black men in the US were deliberately denied medical treatment – has understandably led to deep mistrust of medical research in these communities.

MICHELLE D'URBANO

Yet history also teaches us that ethically broadening the diversity of research participants builds new knowledge that is widely applicable. An example is the story behind PCSK9 inhibitors, drugs that are extraordinarily effective at lowering the type of cholesterol associated with cardiovascular disease by targeting a protein called PCSK9. By ensuring African Americans were included in her studies, Helen Hobbs at UT Southwestern Medical Center in Texas discovered that certain mutations in the gene that makes the protein – common in African Americans but rare in people of European descent in the US – are associated with a 40 per cent lower level of harmful low-density lipoprotein cholesterol. This led to the development of safe PCSK9-blocking drugs that are far more potent than statins.

Our own research, from prenatal diagnostics to solid organ transplantation, provides similar examples of the need for diversity in research. Another recent study found that, because cancer research employing the gene-editing tool CRISPR draws on "reference genomes" that are insufficiently diverse, it is prone to missing genes that, when mutated, promote the development of cancer among those of African descent. Only more inclusive research will improve these outcomes.

Studies show that research by diverse teams has the greatest impact. This supports students from historically excluded communities to pursue careers in science. We must also encourage scientific inquiry that puts equitable practices at its heart and seeks to repair justified mistrust of the scientific community – for example, by partnering with historically Black medical colleges in the US.

Finally, we need continued support of large-scale initiatives that mandate more inclusive representation, like the US National Institutes of Health's All of Us programme, which is building huge databases of health data from more than 1 million people with varying backgrounds. It is past time for leaders across the scientific community to commit to a future of equal, open science that benefits everyone. ▮

Michal Elovitz is at Icahn School of Medicine at Mount Sinai, Stephen Quake is at the Chan Zuckerberg Initiative and Hannah Valantine is at Stanford University

Field notes from space-time

A massive problem

Traditional explanations of why objects have mass can feel unsatisfactory. Particle physics helps, but it doesn't answer everything, says **Chanda Prescod-Weinstein**

Chanda Prescod-Weinstein is an assistant professor of physics and astronomy, and a core faculty member in women's studies at the University of New Hampshire. Her research in theoretical physics focuses on cosmology, neutron stars and particles beyond the standard model

LAST month, I wrote about the challenge of explaining space-time. To give people a feeling for what I mean when I say that space-time is curved, sometimes I talk about a rubber sheet with a ball sitting on it. I point out that the ball causes the sheet to curve and the curvature of the sheet literally shapes where the ball will roll. I say we can think of this as an analogy for our local star – the sun – curving space-time around it. How is the sun able to do this? Because it has mass.

Increasingly, I think it is strange (and perhaps lucky for me) that no one ever follows up by asking: "But what is mass?" We science communicators can take it as a given that people have an intuition for the meaning of mass (that it is the amount of stuff available for gravity to pull on) and that our only task is to help people understand how it is distinct from weight (a measurement of the force that results from local gravity pulling on a massive object).

But perhaps audiences should be unsatisfied with this. I certainly feel I could be doing a better job. So I checked an authoritative text: my favourite dictionary.

The first thing I learned is that my sense of "mass" isn't listed first in the *Oxford English Dictionary*. That is reserved for the religious practice. Mass, in the physical sense, is labelled "n.2". And within this entry, there are, unbelievably, nine multi-part definitions.

2a defines mass as: "A coherent body of matter of unspecified or indeterminate shape, and usually of relatively large bulk; a solid and distinct object occupying space." My physicist's intuition suggests this is a generalisation of definition 5b, which states: "*Physics*. The quantity of matter which a body contains, as measured by its acceleration under a given force or by the force exerted on it by a gravitational field; an entity possessing mass. Strictly distinguished from *weight*, although colloquially the two terms are often used interchangeably."

I might modify this to say that mass is a statement of the quantity of matter which a body contains and that will experience acceleration due to any force applied to it. Isaac Newton's second law even gives an equation that tells us that the amount of force an object is experiencing is proportional to how massive it is. But this raises some questions.

"Mass can change: I just ate an avocado, and now the leftover skin and pit are less massive and I am more massive"

Does mass exist outside of how an object is affected by forces? Where does mass come from? And what counts as matter?

Let's start with a simple piece of information we feel confident about: an object's mass is intrinsic. In other words, mass is a property the object carries around with it, wherever it goes and whatever it is interacting with. Of course, mass can change. I just finished eating an avocado, and now the leftover skin and pit are less massive and I am more massive because I transferred the flesh of the fruit into my body. This hints at another fundamental property: usually, mass is conserved. The avocado's innards didn't just disappear, they transferred to a different location, and my body will use a lot of this to generate energy that I will use to do things like write this column.

Even if I have convinced you that mass is inherent to matter, this raises the question of why the traditional definitions feel unsatisfactory and even tautological. Force is proportional to mass, and mass is a quantity whose measurement exists in relation to forces. Here, particle physics comes to our rescue.

Sort of. The nice thing about particle physics is that I can now say that a massive object, like an avocado, is made up of more fundamental constituents. There are compounds, which are made of molecules, which are made of atoms, which are made of protons, electrons and neutrons. Electrons are indivisible elementary particles, unlike protons and neutrons, which are composed of different combinations of up and down quarks, which, in turn, are elementary particles. So, an avocado gets a lot of its mass from the mass of electrons and the masses of up and down quarks. There is an additional element to mass: the binding energies that hold these particles together. Special relativity teaches us that mass and energy are fundamentally equivalent.

If elementary particles aren't, in effect, made of other things, why do they have mass? The answer in the case of most particles in the standard model, our best description of nature at this scale, is related to the Higgs boson. The boson is one manifestation of the Higgs mechanism, which interacts with leptons like the electron as well as quarks in a way that leads to them developing the inherent property of mass. For now, I believe this is the best explanation of why objects have mass. But it is incomplete. We can't show how the Higgs mechanism works for neutrinos, another elementary particle. As a theoretical physicist, this is a delight: massive problems like this are what we live for. ▮

Chanda's week

What I'm reading

Rosamund Bartlett's translation of one of my favourite novels, Leo Tolstoy's Anna Karenina.

What I'm watching

I recently caught up on every episode of reality TV show Vanderpump Rules *so I too could understand Scandoval (a much-discussed relationship revelation in the series).*

What I'm working on

I've started drafting my second book, The Edge of Space-Time*, which gets its title from a textbook co-authored by Stephen Hawking.*

This column appears monthly. Up next week: Graham Lawton

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A byte to eat? How your dinner might soon be grown by robots

The world's population is growing, and we must take care of our planet. The UK is leading the way with autonomous farms. These farms combine technology with agricultural expertise to transform crop cultivation. By harnessing robotics, AI, and data-driven insights, autonomous agriculture offers a sustainable approach to farming.

Kit Franklin, Senior Engagement Fellow at Harper Adams University, is a pioneer of this approach. He launched the 'Hands Free Hectare' project in 2016, growing the first arable crop remotely, without operators in the driving seats or agronomists on the ground. After refining the systems over several crops, the project has expanded to the 'Hand Free Farm' which is spread over 35 hectares, much more like a regular farm.

But why do we need autonomous vehicles to farm, if regular human driven machines already work well? According to Kit, "Over the last 100 years in the UK, we would have had two and a half million people working on our farms and now we have more like half a million. To cope with that reduction in people we've invested in huge tractors. They cover massive areas of land and that's been great for productivity. But it's not been good in terms of precision."

Kit argues that by using smaller autonomous machines, they can apply fertiliser and pesticides more precisely, whilst also reducing the compaction of the soil. Smaller machines also require less power, so powering them with electricity rather than diesel becomes possible.

"It's certainly not automation for the sake of automation, it's automation to enable us to farm better, ultimately more sustainably and helps with the journey to net zero that UK agriculture is on."

You can find out more by joining Kit Franklin at New Scientist Live this October. He'll be on the 'Our Planet' Stage at 3.45pm on Saturday 7 October. At the show you can also check out our incredible feature on the future of food and agriculture and chat to the experts who are revolutionising how we can feed the world more efficiently and sustainably. **Find out more at: newscientist.com/future-of-agriculture**

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Editor's pick

Grappling with imminent prospect of scary warming

10 June, p 32

From Trevor Prew, Sheffield, UK

Even with 1.5°C of warming on the very near horizon, the vast majority of humanity seems to be in denial of climate change and is failing to act. Perhaps calling it climate change is part of the problem. I suggest always calling it human-induced warming or fossil fuel-induced warming, so the cause is clear.

I would also like it more clearly stated that 1.5°C of global warming is the average of the oceans and the land. The oceans warm more slowly, which means average land warming is already higher than 1.5°C.

From Fred White, Nottingham, UK

We are at more than 424 parts per million (ppm) of carbon dioxide in the atmosphere and rising. With no reference to temperatures, the chemist James Lovelock – who proposed the Gaia hypothesis – considered approaching 450 ppm to be reckless; by then, damaging, irreversible positive feedbacks would start locking into place.

Unlike speculating about temperatures, CO_2 levels have the politically inconvenient property of clearly quantifying the carbon quota remaining for nations over the next 10 years before reaching Lovelock's point of no return.

From Steuart Campbell, Edinburgh, UK

You say that carbon cuts alone won't be enough to reverse catastrophic climate change. I agree. Measures introduced so far will have very little effect. Emissions continue to rise, even accelerating. This is doomsday unless something drastic is done.

Fiddling with carbon capture is never going to hack it. We don't have time for such tinkering, even if it would have any effect, which I doubt. To get the temperature down, there is only one practical method and that is to shade the planet, sending enough solar radiation back into space.

One clever method has been proposed by Stephen Salter at the University of Edinburgh. His "marine cloud brightening" makes use of Earth's own cloud system by creating brighter, more reflective clouds over oceans. This would be deployed first, and perhaps only, in the Arctic to refreeze the ocean there. That may be enough to halt global warming and even bring the global temperature down.

We can talk to the animals, so chat with ET is possible

27 May, p 27

From Drew Haffenden, Dauphin Island, Alabama, US

Chris Impey doubts the prospects of communicating with aliens, saying that despite sharing 99 per cent of our DNA with chimps, we can't communicate with them. However, humans have been making themselves understood by chimps for 50 years. We have been communicating with other animals, and they with us, for thousands of years.

Communication isn't about sharing a language, but understanding what another living creature's message is. I am sure Impey would be able to understand and respond to a rattlesnake's rattle.

From Daniel Magasanik, Melbourne, Australia

Impey doesn't mention another reason for caution in contacting aliens, even if they are assumed to be benevolent. They might freely make technologies available to us that are far more advanced than our own, thinking that they could only help us. They may assume that we don't suffer from the dysfunction and conflicts that plague our (so-called) civilisation and that we wouldn't put such technologies to destructive uses.

From David Myers, Commugny, Switzerland

The reason we can't communicate with chimps is because they aren't sufficiently intelligent, but this has no bearing whatsoever on whether we could communicate with an alien species clever enough to detect our messages.

AI in movies will be theatre's gain

3 June, p 16

From Tony Budd, Wickford, Essex, UK

Regarding negotiations between actors in the US and the film industry over the use of artificial intelligence to mimic performers on screen, it seems to me that if this technology takes over film, TV and online drama, then there will be a huge boost for live theatre. Seeing real actors on stage will be everybody's dream.

Growing brains in a dish does raise many issues

10 June, p 21

From Eric Kvaalen, Les Essarts-le-Roi, France

Michael Le Page says that brain organoids grown in labs are nothing like real brains, that they are "bunches of brain cells just a few millimetres across that are nowhere near even a simple animal brain".

Even so, that is a lot bigger than many animal brains. The whole nervous system of the nematode *Caenorhabditis elegans* only contains about 300 neurons.

If consciousness arises out of brains, then we should stop these experiments. If it doesn't, then we should reject materialistic theories of consciousness.

Changing stance is heartbreaking to see

3 June, p 43

From Karen Dawn, DawnWatch, an animal advocacy charity, Santa Barbara, California, US

Though it is great to see animal issues covered in *New Scientist*, it is heartbreaking to see Peter Singer, who was once a great voice for animals, even contemplating the idea that their farming and humane slaughter might be considered ethical. Can you imagine Gloria Steinem discussing types of sexism that she now thinks might be ethical?

Don't just freeze your head, but faeces too

4 March, p 35

From Keith Thomas, Richmond, North Yorkshire, UK

While not wishing to promote the freezing of heads more than sense dictates, it did occur to me that a severed head isn't just missing the rest of its natural form, but also its microbiome – increasingly recognised as an additional dimension of health and personality. To partially compensate for this, perhaps a frozen head should be accompanied by a personal stool sample to allow for a more complete future recombination.

Pack it in please, supermarkets

10 June, p 44

From Martin Pitt, Leeds, UK

I do believe a basic bag-filling algorithm, of the sort described by Peter Rowlett as "a simple rule a computer program can mindlessly apply", is already being used by the supermarkets that deliver to my home. Considering no factor other than filling space, sliced bread is routinely squashed out of all recognition by bottles, jars and cans and has to be rejected. ▮

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Loss and damage

Photographer **Fabeha Monir**
IIED; Panos Pictures

THE summer monsoon in Bangladesh can spell trouble. When its rains are too heavy, major floods can tear through buildings and crops, stranding millions of people and claiming lives. But where rains are too light, drought can strike. Together with rising sea levels and coastal inundation, this leads to water sources becoming saltier, with all these effects heightened by climate change.

These photos by journalist Fabeha Monir illustrate the impact that an increasingly unpredictable climate is having on the people of Bangladesh. “We don’t have to wait decades for a preview of our future transformed by rising seas,” she says. “It’s crucial to show the tangible and intangible loss and damage our peoples are facing.”

The population there has struggled to get support to deal with such issues – but that may be changing. Researchers at the International Institute for Environment and Development and the International Centre for Climate Change and Development have been visiting communities in Bangladesh whose livelihoods have been hit by climate change, in order to better understand how they can be helped.

The images show (clockwise from top left): Aklima Parvin, whose skin darkened due to consuming high-salinity water, exposing her to discrimination; a haul of shrimp, once pushed as an alternative for rice crops due to saltier waters, but today’s shrimp farms make seawater inundation and salinity problems more likely; Md Yusuf Ali growing vegetables – a challenge due to increased soil salinity and drought; a pond dug in Gabura by the government and a charity – a vital water source.

Gege Li

Let science refresh your mind

Travelling is a great time for a rethink, whether about the human mind or the evolution of cats – or even the importance of red algae for Earth, says **Simon Ings**

LOOK back and ask yourself where so many of your good memories of trips away, and your unexpectedly rich strands of thought, began. Often, it can be when messing around near water – or, if you are in the right place, exploring rockpools or tide pools.

In *The Jay, The Beech and the Limpetshell*, Richard Smyth, who creates *New Scientist*'s quick crosswords, rediscovers the natural world as he and his children explore Whitley Bay in north-east England, and woods and moors nearer to home in Yorkshire. The young, Smyth discovers, are natural explorers and questioners. We can, we should, learn from them.

All living things deserve our respect. Inevitably, though, we will end up picking favourites. Cats have done well out of this arrangement, dominating both savannah and sofa through the simple expedient of remaining remarkably themselves over evolutionary time. *The Age of Cats* by Jonathan Losos investigates their extraordinary success.

MOSTOVYI SERGII IGOREVICH/SHUTTERSTOCK

Why do cats grow up to be cats, and why do dogs look like dogs? As *New Scientist* sci-fi columnist Sally Adee (see her sci-fi picks, right) gathered material for her book on the role of electricity in biology, researchers were uncovering electricity's role in giving living things their shape. *We Are Electric* is Adee's thrilling scientific detective story, a rich history that brings us up to date with the latest research.

Where there is life, there is constant change. *The Earth Transformed* by Peter Frankopan (see recommendations, below) is an epic history of the human effort to understand, withstand and maybe even control our environment. Its tale of the rise and fall of civilisations makes for a sobering read, but also one full of challenges and hope.

Coming to terms with climate change is also the subject of Christina Gerhardt's *Sea Change*. Its essays, maps, art and poetry place small islands (vanishing under rising seas right now) at the centre of the climate story. This is a refreshingly different perspective on a problem that, she writes, is all too often "viewed from space".

Now that we are barely more than a human lifetime away from mining the moon and prospecting on Mars, space is looking more thrilling. But such excitement is deflated by Justin Hollander's *The First City on Mars*, a bricks-and-mortar account of terraforming written by an urban planner.

All things considered, it is just as well that we are thinking a lot more about the global food system. In *Ravenous*, food entrepreneur Henry Dimbleby and journalist Jemima Lewis explain how plate and planet have ended up hostage to practices that are now entirely unsustainable.

The authors aren't short of solutions, and neither is *The Seaweed Revolution*, Vincent Doumeizel's exhilarating vision of how seaweed and marine algae could feed people and clean up the seas. Apparently, adding red algae to ruminants' diets could cut their methane output by 80 per cent.

The books we'll be packing...

MLA/SHUTTERSTOCK

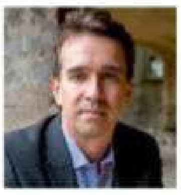
Giorgio Parisi is a Nobel winner and author of *In a Flight of Starlings*

I deeply admire Stephen Jay Gould's limpid writing, polemical verve and his extensive cultural knowledge that allows the reader to relate seemingly disconnected facts. I read *The Flamingo's Smile* 30 years ago and will have the great pleasure of rereading it on holiday.

R. RICCIUTI/GETTY

Claudia Hammond is the author of *The Keys to Kindness*

My choice is *Awe* by Dacher Keltner because the book is the product of 15 years of research demonstrating the psychological benefits of finding awe. A holiday feels like a great time to put Keltner's excellent advice into practice.


CHARLES MORIARTY

Peter Frankopan is the author of *The Earth Transformed*

I'm looking forward to *In Search of Ancient Tsunamis* by James Goff, which combines history, geology, geomorphology, anthropology and archaeology. Plus, as a treat, *The Great Weather Syndicate* by George Griffith, a 1906 thriller where ruthless entrepreneurs control the climate.

ALISE BLACK

Suzie Sheehy is a physicist and author of *The Matter of Everything*

I'm drawn to books for their perspective-shifting magic. I'll be reading *Broad Band* by Claire L. Evans, celebrating the women involved in making the internet. And I plan to revisit the incredible science of Indigenous peoples in *The First Astronomers* by Duane Hamacher.

New Scientist Book Club

The Ferryman is the first pick for our new book club. Read along with us at **newscientist.com/bookclub**

There is plenty of rethinking about everyday experience on offer, too. Andy Clark's *The Experience Machine* sets the stage. Rather than perceiving the world directly, Clark explains, our minds must make ever finer predictions about what is out there.

The difficulty of working out where the self stops and the world begins probably explains those moments when we feel a presence at our backs. Ghostly sensations are real enough, but the science is still unfolding, as *Presence* by Ben Alderson-Day shows.

> "All living things deserve our respect. Inevitably, we will pick favourites. Cats have done well out of this arrangement"

In *Travellers to Unimaginable Lands*, meanwhile, Dasha Kiper talks to those caring for people with dementia. Carers often struggle, responding to the person they knew rather than the person as they are now. Reality and the carer's perception peel apart disturbingly in this highly original, compassionate work.

There is much to learn elsewhere too. Viorica Marian's *The Power of Language* shows how valuable multilingualism can be, for the individual and for society. Then in *Once Upon a Prime,* Sarah Hart teases out surprisingly rich connections between literature and mathematics.

What if you have no time to read for fun? Throw away your clock, of course. Or at least read Jenny Odell's *Saving Time*, which urges us to develop a deeper relationship with moments and their passing. ▮

Simon Ings is a writer and critic based in London

Find your fictional future

Great sci-fi offers many ways to escape our troubled world and teaches us how to grapple with it, says **Sally Adee**

TIME off is for relaxing with a book, and sci-fi luckily meets our needs with a wonderfully diverse palette of approaches to the grief and trouble surrounding us. Some stories shine a light on our worst truths, others offer escapes to worlds as beautiful as they should be, and then there are those that blow your mind so thoroughly you can't think any more.

The best canonical sci-fi puts the thinnest veil on reality to show us just how close we are to the world we fear. The London you encounter in Temi Oh's *More Perfect* is grittily familiar – making the near future she paints queasily plausible, including the brain implant that is being forced on citizens and the political chaos this foments. It weaves an intriguing tapestry of references, from the classical story of Eurydice to the neuroscience of consciousness, set against a drumbeat of dread.

Realism can also probe internal landscapes. In *Fractal Noise*, Christopher Paolini's moody prequel to *To Sleep in a Sea of Stars*, an investigation of a baffling extra-planetary anomaly functions as a metaphor for the path that must be walked to move beyond life-altering grief.

The psychology of grief goes well beyond realism in Nicholas Binge's *Ascension*, whose nested set of narrators pursue one another up a mountain that has inexplicably appeared in the middle of the Pacific Ocean. And that is the least mind-bending thing that happens in this allegory of our inability to cope without closure.

What is grief if you can't die? *Rubicon* seems like a standard space cadets versus monsters story. But while J. S. Dewes spins a fast-paced, popcorn movie tale, be prepared for a twist that will smack the popcorn out of your hand and leave it on the floor with your jaw.

Grief can be planetary in scale, too. Emily Tesh's *Some Desperate Glory* is a keen observation of how catastrophe creates radicalism. In a book that is a heady mix of military space opera and sensitive character study, a girl bred for brutal combat begins to question the narratives that formed her.

Not everything is so heavy. The short stories in Julianna Baggott's *I'd Really Prefer Not to Be Here With You* are so snackable they go down without touching the sides, but their deeper themes sneak in and stay there. Nick Harkaway's *Titanium Noir* is similar. It is good, old-fashioned gumshoe noir that has been transformed into sci-fi, with some primordial Greek mythology.

***The Lies of the Ajungo*, Moses Ose Utomi's novella, also sneaks in under the emotional radar. It is a short page-turner about a young boy in an apocalyptic city who must venture into a terrifying desert on a quest to bring back water.**

Longer and denser by far is Justin Cronin's *The Ferryman*, a wild ride through so many genres they defy description. If you can only read one book this summer, make sure you don't miss this one. (And you can read along with New Scientist Book Club, see top of page.)

For readers who want an escape from reality that will really blow their minds, Christopher Priest offers a left-field interpretation of climate data in *Expect Me Tomorrow*. Out in hardback, this is an ambitious historical novel into which the sci-fi has been laid like gold veins, questioning just how much we really know about the future.

And for an extra challenge, Emma Mieko Candon's *The Archive Undying* won't disappoint. Here, city states were once controlled and defended by AI god-kings. When their code corrupted, the AIs violently destroyed all the people who lived there, apart from an immortal vassal who now carries the burden of the citizens' collective trauma. Succeeding in his new mission means he must get himself together – in more ways than one.

Captivating, surprising and utterly unique, these are the novels that will help you get to grips with the future that is here, or fast approaching. ▮

There are plenty of sci-fi stories to bring with you on your travels

IMAN RAZA KHAN/GETTY IMAGES

Sally Adee is a science journalist and author, she also writes *New Scientist*'s science fiction column

Brilliant reads for young minds

Baby frogs, puberty, enhanced humans, climate change – exciting books on these subjects will engage kids of all ages, says **Imogen Russell Williams**

MOMO PRODUCTIONS/GETTY IMAGES

CHILDREN can easily get bored on holiday. Best to prepare well and make sure they have some beautifully designed, captivating non-fiction, as well as brain-stretching science fiction.

This year, watery worlds are very much to the fore. Maggie Li's *Little Life Cycles* board books are delightful first science offerings for babies, with bright colours, dynamic images and growing room built into their sparse language so preschoolers will get progressively more from them as they revisit. In *Frog*, for example, circular cutouts entice little fingers as a single egg transforms into a frog, avoiding the perils that wipe out the other frogspawn before the life cycle starts again.

For readers aged 5 and over, the inspiring writer Nicola Davies teams up with illustrator Catherine Rayner in *Emperor of the Ice*. Rayner's snowy images invoke an Antarctic chill nicely, while Davies's rich, stately text describes the breeding cycle of the emperor penguin – and the dangers and disruption facing this species as the sea ice melts.

Readers aged 7-plus who enjoy a frisson of sub-aquatic fear will want to plunge headlong into *The Deep*, an Usborne Extreme Planet lift-the-flap book by Laura Cowan, illustrated by Qu Lan, that bristles with the bizarre and the luminously grotesque. From the twilight zone several hundred metres down to the deepest place on Earth, children will find barreleye fish with see-through heads, parasol sponges described by Cowan as "evil fairies" and bloody-belly comb jellies that "eat everything they can swallow".

For teenagers, *The Girl Who Broke the Sea* by A. Connors is an ominous, evocative science-fiction thriller set in a deep-sea mining base on the ocean floor, featuring a girl with a chequered past who becomes confined to a high-pressure environment.

Conservation and climate remain popular in non-fiction for all ages. A stand-out title from last year aimed at readers aged 8 and over is *Bright New World* by Cindy Forde. This presents a vision of the future in which every aspect of human life has been overhauled in the interests of building a better planet. Dealing squarely with the catastrophic realities of climate change, it is infused with a sense of hope and excitement, celebrating climate activism and scientific endeavour via Bethany Lord's soaring illustrations.

> **"Plenty of compelling children's non-fiction looks inward instead, at the wonders of the human body"**

Ecology for Beginners by Lan Cook and Andy Prentice is geared for readers aged 10 and over, conveying appropriately sophisticated concepts – like the difference between biomes and ecosystems, or positive and negative feedback loops – all told in straightforward language and humorous speech bubbles. While it unflinchingly lays out the realities of global warming, its factual calm leaves the reader informed, with a sense of possibility rather than panic.

Plenty of compelling children's non-fiction looks inward instead, at the wonders of the human body. Rachel Greener and Clare Owen's inclusive, simple and candid *Growing Up* presents a reassuring overview of puberty for the over-6s, covering physical changes and shifting identity in a way that will help adults worried about finding the right words.

There is further anatomical exploration for those aged 7-plus in *Thirty Trillion Cells* by Isabel Thomas, perhaps the best contemporary writer of children's non-fiction. Dawn Cooper's luminously colourful illustrations and Thomas's lively, thought-provoking phrases ("fat is like bubble wrap for your body") make for an absorbing, original account of bodily systems and processes.

In the same vein, for older children and teenagers, Ben Martynoga's *Explodapedia* series, illustrated by Moose Allain, kicks off with *The Cell* and *The Gene* – accessible, entertaining and focused on the history of science, as well as cutting-edge discoveries.

The augmented body is the subject of *Human 2.0* by Patrick Kane, illustrated by Samuel Rodriguez. It is an intricate exploration of medical engineering for those aged 7 and over, investigating the ever-developing relationships between humans and technology, from cochlear implants to bionic limbs.

Finally, for older teens, the dark potential of virtual reality is explored in *A Game of Life or Death* by Triona Campbell. It is a thriller in which Asha, a gifted hacker who discovers her beloved sister Maya dead, decides to infiltrate her sibling's former employer to expose the frightening secrets of the VR game she blames for Maya's death.

All in all, there is plenty to enjoy and to brighten dull days. ▮

Imogen Russell Williams is a writer and critic based in London

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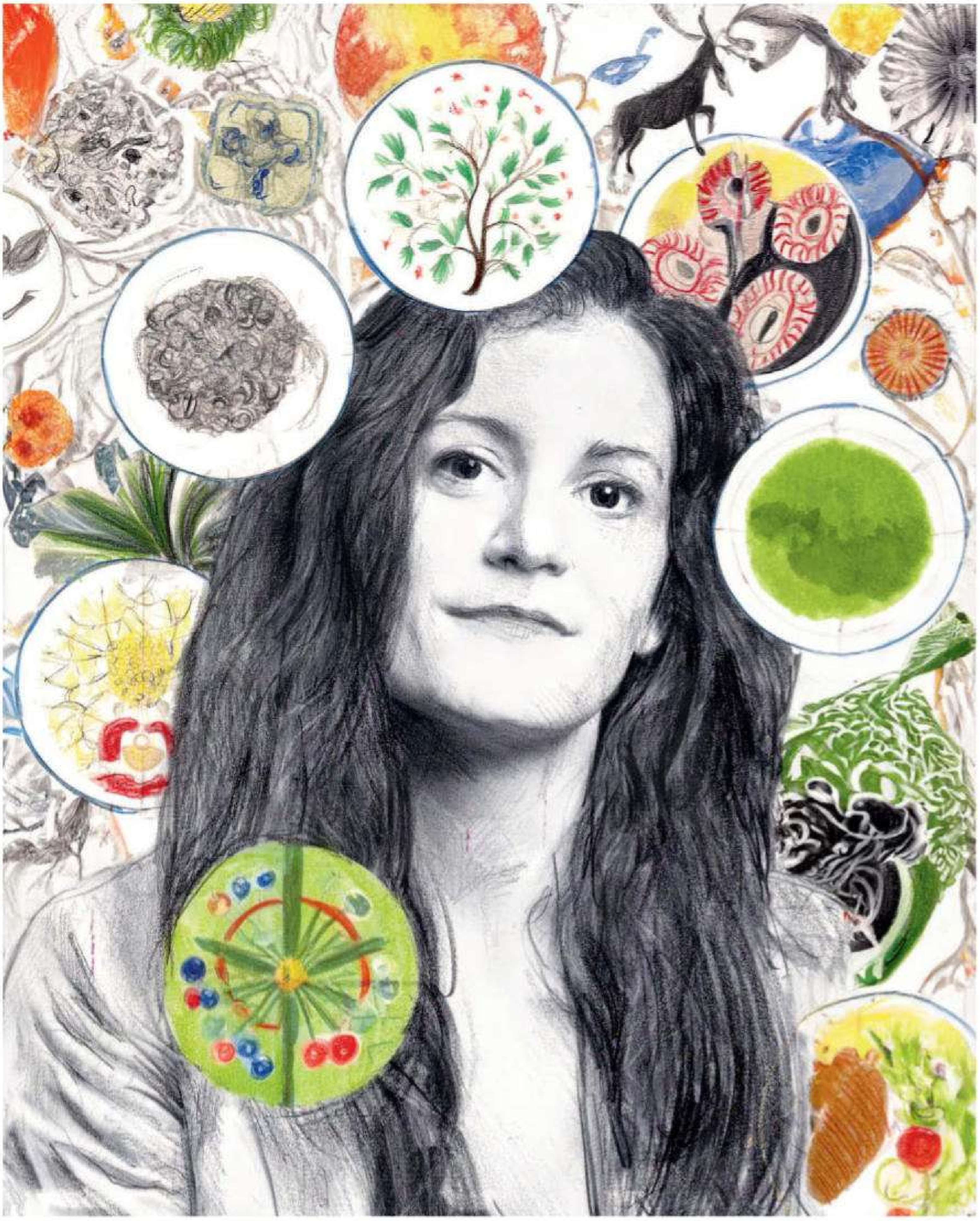

NABIL NEZZAR

"We're reframing life by thinking about it as a lineage"

Astrobiologist **Sara Imari Walker** is developing a deeper description of what life is. She tells Thomas Lewton how it has already led to discoveries about the minimum complexity something must have to be alive

What is life? It seems like a simple enough question. And yet the truth is that we can't explain why one lump of matter is alive and another is not, which is a problem if you want to figure out how life on Earth began – never mind whether it exists elsewhere. But Sara Imari Walker, a theoretical physicist and astrobiologist at Arizona State University, has a radical new theory that purports to transform our understanding of what it is to be alive.

Most attempts to describe life use Earth as a blueprint. Instead, by pushing past cells and their chemistry to general principles about how complex objects come into existence, Walker claims to have reached a deeper understanding. The idea, known as Assembly Theory, explains why certain complex objects have become more abundant than others by placing fresh emphasis on their histories. Now, Walker and her colleagues are testing the theory on lab-grown microworlds. In experiments, they have already discovered a threshold – namely the number of steps on the way to complexity – that seems like it must be met for something to be considered alive.

If Assembly Theory proves correct, she tells *New Scientist*, it will redefine what we mean by "living" things and show that we have been going about the search for life beyond Earth all wrong. In the process, she says, we could even end up creating alien life in a laboratory.

Thomas Lewton: How do we define life at the moment?

Sara Imari Walker: A popular definition, often used by NASA, is that life is a self-sustaining chemical system capable of Darwinian evolution. Every word in there is problematic. I don't think life necessarily needs to be chemical. It's a much more abstract phenomenon. Life is about how information structures material objects and what objects are selected to exist, regardless of whether those things are chemical or not.

As for "self-sustaining", well, first you must define the boundary of the self. Parasites are interesting because they're not self-sustaining, but if you include their host then they are. Life depends on its environment. A lot of the issues with defining life always come from us wanting to draw a hard boundary. We want to be able to categorise things and put them in the life bin or the not-life bin. But there are always these challenging boundary cases. We shouldn't assume that we know what life is from the outset because that whole enterprise has failed over many decades.

Haven't we made some sense of what life is and how it began?

A lot of people focus on the RNA world scenario, for example, which posits that self-replicating RNA molecules appeared as a first step, before DNA or proteins. But they're still missing the bigger story about how complex chemical systems actually arise. This is a problem because we're building the answer we expect into the design of origin-of-life experiments. Everybody has narrowed in on the features of life that they think are important, but we haven't gotten to that deeper understanding that allows us to connect all these pieces together.

How are you getting to a deeper understanding?

A lot of people want to argue that the universe generates complexity for free. In standard physics, we think everything can happen spontaneously and life is just some very rare fluctuation. But the universe is this vast space of possible things. There are 118 known elements, and molecules are made from many of these elements, but there's not enough material in the entire universe to make even one copy of every possible molecule. And that's just counting simple molecules, I'm not including big molecules like DNA or proteins. ›

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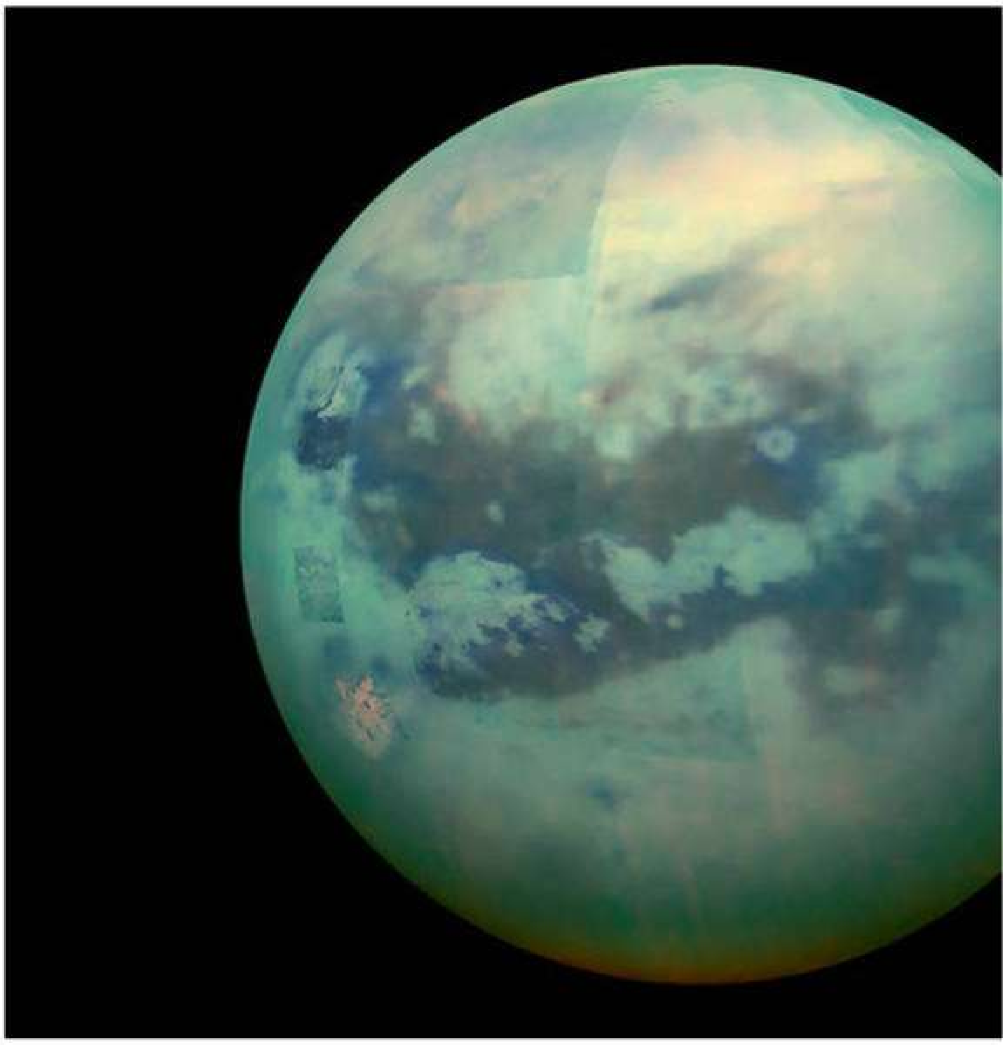


Astronomers are planning to use Assembly Theory to look for life on Titan, one of Saturn's moons

NASA/JPL/UNIVERSITY OF ARIZONA/UNIVERSITY OF IDAHO

So the likelihood of creating even a moderately complex object, say a DNA polymer, by randomly attaching atoms is exponentially low. If you try to create that twice it's almost impossible. There's never been a physics that has dealt specifically with this problem.

How does Assembly Theory try to deal with this?

The key conjecture of Assembly Theory is that the only way for us to observe complex objects is through a process of evolution and selection: where selection is based on things that have been built in the past, and they are used to build subsequent objects. This series of stages leads us to a "complexity threshold" and only above this do you see things that are products of life. Along with Lee Cronin at the University of Glasgow in the UK, our hypothesis is that life is the only physics that builds these high complexity objects. Sometimes I say that life is the physics that decides what gets to exist.

What do you mean by "objects"?

The fundamental objects in Assembly Theory are the emergent complex structures, not fundamental particles like quarks or electrons or photons. We define objects within an "assembly space", which contains all of the ways of building up an object from its basic building blocks. So an object like a molecule isn't defined by its three dimensional configuration that you might hold in your hand, and it's not defined by its mass or electric charge. The object is actually the ways of building the molecule. These histories, which converge on a particular structure that we see, are the object.

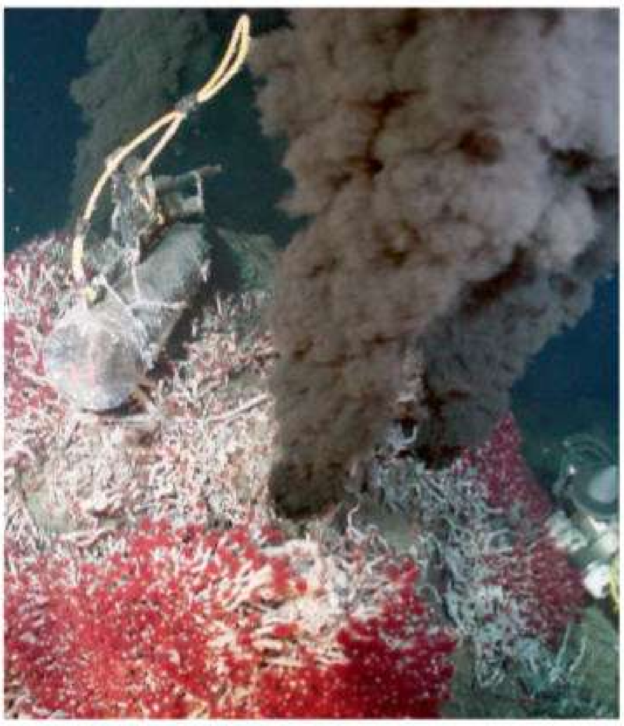
An electron can be made anywhere in the universe and has no history, so it's not a very interesting object. You are also a fundamental object, but with a lot of historical dependency. You might want to cite your age counting back to when you were born, but parts of you are billions of years older. The ribosomes that play a key role in translation of information from DNA to protein, for example, are believed to have been around on Earth for nearly 4 billion years. The specific molecules in your body aren't that old, but the lineage of these objects being reconstructed goes back that far.

From this perspective, we should think of ourselves as lineages of propagating information that temporarily finds itself aggregated in an individual. We are our history. So, we're reframing life by thinking about it as a temporally extended structure. It's a lineage, not an individual.

It seems intuitive that complex living objects are made from simpler objects. In what way is this an explanation for life?

We're saying that there's a different kind of complexity, which is assembled. On a meteorite you can have a chemical mixture of many molecules, but because none of them are produced in enough abundance you get this undifferentiated tar. From the perspective of Assembly Theory, no assembled structures have been selected out of that. It's a flat complexity that is very different to the kind of complexity we're talking about. According to Assembly Theory, this is why a meteorite has little to do with life.

Our key argument is that if something is hard to make, and requires many steps, then you're not going to see an abundance unless there was a selected pathway that makes it. In a meteorite, molecules with high assembly level are produced in such small amounts by random processes that they are undetectable. But if an object is alive, then selected pathways can reuse parts from the object's history to make an abundance of structures with high assembly. That's the only way to traverse this exponentially growing space of all possible things and so explain the existence of life. You have to trace out historically contingent paths, and we're trying to find out what the minimal number of steps needed to get there is.



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Deep sea vents may not be the only place where life on Earth began

> “We want to discover alien life by making it from scratch in the lab”

What makes certain pathways “selected”?
If I was wildly conjecturing, I’d say there’s a sort of force that moves objects through assembly space to generate higher assembly objects, which is why the biosphere evolved complexity over time. But I don’t know if it’s a force like in standard physics, we’re trying to think about that. My intuition is that life is the physics that builds and grows possibility spaces. There’s some sort of driving force that the universe is trying to explore in order to make as many objects as it can. It’s trying to maximise the number of things that exist, and life is the way of doing that.

How are you testing this in the lab?
From our general theory about how objects assemble, we predicted that a threshold for life exists. Cronin and his team took a whole bunch of chemical samples from non-living and living materials. Using a mass spectrometer, which measures molecular fragments, they measured the “assembly index” of an object. This is the minimal shortest path required to build it.

The threshold for life seems to be an assembly index of about 15. We don’t know if the number 15 is universal or specific to chemistry on Earth. But the fact that there is a threshold, above which we only observe molecules produced by life, is really significant.

We haven’t found any non-living materials that have an assembly index above 15. This lack of false positives is unusual in origin-of-life science. When astrobiologists, like me, look for life, we seem to think that false positives are inevitable. We’ll find atmospheric oxygen on an exoplanet, or amino acids on meteorites, even though there’s no life there. This tells us that we’ve been looking at life wrong. If life is a real category of nature, and we understand the physics, there should be no false positives. It’s either life, or it’s not.

So, you could you use this assembly index of life to search for alien life?
Yes. We’re applying the idea of an assembly index of 15 to future flight instrumentation for NASA missions. NASA’s Dragonfly mission, set to launch in 2027, will be the first to visit the surface of Saturn’s moon Titan. It’s a good example of the advantage of taking a more general approach to what life is because Titan is very different to Earth: the surface of Titan has hydrocarbon lakes. We don’t expect anything like Earth life to evolve or live in this environment, so if we want to find out if life is on Titan, we need an agnostic technique. My group is now working on determining how we might be able to detect high assembly molecules. We’re working with NASA to ensure that their existing mass spectrometry instrumentation has high enough resolution to detect high assembly molecules.

Life detection on other planets or moons has so far been done by analogy to life on Earth, but this underestimates just how different alien life could be. Ultimately, I want to use Assembly Theory not just to detect life on other planets, but to predict what kind of life-assembling chemistries we expect to evolve on different planets.

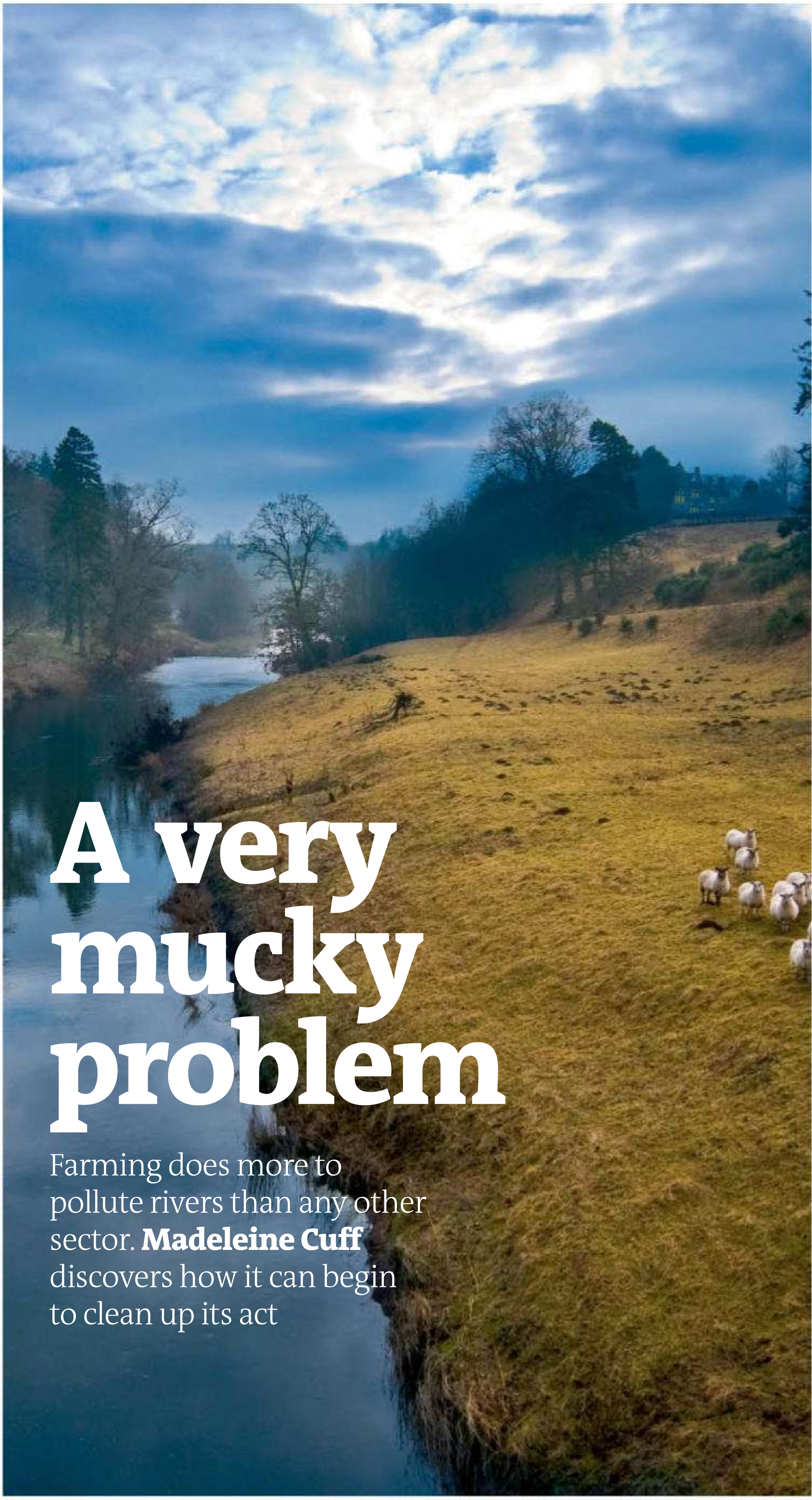
How is Assembly Theory going to help you work out the origin of life, on Earth or elsewhere?
I actually think the origin of life was a planetary scale transition. The opposing, reductionist picture is that cells emerged in one environment, like at an isolated hydrothermal vent deep under the sea, and then they expanded over the entire planet.

My view is that geochemistry started to generate more complexity, which changed features of that geochemistry globally. Through these feedback loops, geochemistry transitioned to biochemistry and that led to cellular structures and eventually to humans. You can almost think of it as a condensation across scales from molecules to cells to ecosystems to the planetary scale, all at once.

Is there any way to test that idea?
We would need to build experiments that can explore diverse geochemistries to determine how different conditions could drive selection and the emergence of evolution. An analogy is in the Large Hadron Collider, which was built to explore the conditions at the start of our universe. We need to build a planetary geochemistry experiment to explore the conditions at the start of life.

We can do this with automated chemistry experiments done at scale, which we are working on with Cronin’s team. The ultimate goal is to experimentally search enough of the chemical space of planets in the lab to observe a new origin-of-life event. That is, we want to discover alien life by making it from scratch in the lab. If we can do that, I think we can say we have solved what life is. ■

Thomas Lewton is a features editor at *New Scientist*



A very mucky problem

Farming does more to pollute rivers than any other sector. **Madeleine Cuff** discovers how it can begin to clean up its act

THE rolling English farmland of Dorset, Somerset and Devon might look like a bucolic idyll, but looks can be deceptive. These three counties in the country's south-west are home to hundreds of intensive dairy farms, producing almost a quarter of the UK's milk. Thousands of cows create a smelly problem for farmers: what to do with all the dung? As I drive along the winding country lanes, the stench drifting off nearby fields offers a clue.

My nostrils aside, it is local rivers that bear the brunt. In wet weather, slurry (manure plus water) overflows from silos where it is stored and runs off land into waterways, wreaking havoc on their ecology. The situation is particularly bad in the south-west, but this is a nationwide problem – and it isn't the only damage that agriculture does to rivers. Over recent decades, pressure from supermarkets to provide plentiful food at low prices has pushed farmers to boost livestock numbers, use more fertilisers and pesticides to increase crop yields and remove hedgerows to make larger, more efficient fields. All these actions have knock-on effects, polluting watercourses with soil sludge, toxic chemicals and excess nutrients like nitrogen and phosphorus.

As in other countries, the UK has legislation to reduce the ecological damage caused by farming. But enforcing these rules isn't always easy, even when environment agencies make them a priority. No wonder the UK's rivers are in such a bad state. It sounds like the perfect storm, but, in my travels around the country, I have found green shoots of hope that we can build on to clean up waterways and revitalise the wildlife they support.

This problem isn't unique to the UK. Across Europe, 22 per cent of rivers are significantly affected by agricultural runoff. Things are even worse in the US, where around 46 per cent of

JIM GIBSON/LOOP IMAGES LTD/ALAMY

Manure from livestock releases nitrogen and phosphorus into many UK rivers, including the Till

rivers and streams suffer from excess nutrients and just 28 per cent are assessed as "healthy". Agriculture, which accounts for about 50 per cent of land use in the US, is the leading source of pollution in its rivers and lakes. Even in New Zealand, a country renowned for its pristine natural environment, a recent government report concluded that 45 per cent of the total length of its rivers is too polluted to swim in. It pointed the finger at dairy farming, which has seen cow numbers increase by 80 per cent in the past three decades.

In the UK, about 70 per cent of the entire country is designated as agricultural land. Around one-third of that is cropland, mainly for cereals such as wheat and barley, with most of the rest used for raising livestock. In many ways, farming practices are well suited to the country's climate and ecology. In the wet, western parts, livestock farming dominates to make the best use of plentiful natural pasture, while arable farming is concentrated in the drier, flatter east. But farms have become larger and more specialised over the years and those that run them now use the land more intensively to meet increasing consumer demand for cheap food – particularly meat. In fact, there are now more livestock animals in the UK than people, with 85 million cows, pigs, laying hens and sheep on farms across the country and more than a billion broiler chickens slaughtered last year.

These changes have put increasing pressure on the UK's remaining wild places, particularly its waterways. Farming is responsible for between 50 and 60 per cent of nitrate pollution and around 40 per cent of river pollution in general. In June 2021, James Bevan, the former chief executive of England's Environment Agency (EA) told MPs: "Statistically, the largest sector that is impacting our waters, in one way or another, is the farming sector." The main culprits are excess nutrients from manure and other fertilisers, as well as pesticide runoff. Once in the water, pesticides can damage the health of animals and plants, and excess nutrients reduce oxygen levels, stifling aquatic life. As I walk along the banks of the river Yarty in Devon, I can see the effects. Independent ecologist Gavin Saunders points out the coating of green algae clinging to the gravel riverbed. "That's heightened phosphates in the water causing the algal bloom," he says. "That, in turn, affects the spawning beds of fish and invertebrates."

The UK's environment agencies are charged with ensuring that farming activities don't pollute waterways, but cuts to their budgets have curbed their ability to monitor the situation and take enforcement action. Meanwhile, the problem grows. Take slurry. By law, farmers in England are required to have silos with enough capacity to store at least four months' worth of it on site. But, in recent years, many dairy farms have increased their herd sizes without upgrading their slurry storage in tandem. As a result, there are hundreds of dairy farms across the country where slurry is seeping out of overflowing stores and there are many farmers spreading it onto fields in wet weather, both of which mean the muck runs straight into waterways.

That explains why, as I crouch beside a muddy brown stream in deepest Dorset, my nose is assailed by the stink. "There are too many cows. End of!" says my guide Andrew Locke, a retired EA official and a member of the Axe Vale Rivers Association.

Along the river Axe, algal blooms, as well as sediment pollution and high phosphate levels, have taken their toll, with salmon pushed to local extinction and other fish populations declining. Nevertheless, what

›

In 2013, excess spraying of the herbicide MCPA polluted the river Teifi in Wales

MADELEINE CUFF

Join Madeleine Cuff
Exploring pollution on the river Teifi
For more details: newscientistlive.com

has happened here in recent years shows that better enforcement of existing rules can lead to big improvements.

Things came to a head in 2015, when conservation group WWF and the Angling Trust took the EA and the Department for Environment, Food & Rural Affairs to court for failing to use its powers to tackle pollution on the Axe, which is designated by the European Union as a Natura 2000 wildlife site and a Special Area for Conservation. In response, the EA admitted that "very little" regulatory activity had taken place in the previous 15 years to ensure farmers followed rules governing water pollution, and began an intensive effort to tackle agricultural pollution on the Axe.

An audit of 86 farms, carried out between 2016 and 2019, revealed that 95 per cent weren't complying with slurry storage regulations and almost half were found to be polluting the river. Winston Perry was one of the farmers visited by the EA. His family has kept dairy cows at Harrison Farm in Devon since the 1890s. But when EA officials visited, they confirmed that Perry's slurry storage wasn't up to scratch. "We knew that we weren't making the best use of our slurry, because we were having to spread [it on fields] at times when we didn't want to," he says. The EA visit, which came with the threat of fines and prosecution, pushed Perry to take action. In 2017, he spent £18,000 on a new, bigger slurry lagoon.

Perry's story isn't unique. Since 2016, EA visits have prompted 33 farmers in the Axe catchment to upgrade their slurry storage, with others carrying out repairs to existing facilities. The EA's Louise Weller says the threat of enforcement was critical to pushing farmers to make changes. "The threat of regulation has worked," she says. "So we haven't had to do a lot of enforcement at all." Just nine farms have received enforcement notices, legal documents requiring them to take action. The EA is now planning to roll out this approach to other parts of the country, recruiting 84 advisors to visit farmers in other polluted river catchments. "That's only going to be for the good," says Iorwerth Watkins at the Westcountry Rivers Trust. He points out that it could take a decade or more for the excess nutrients to work their way out of the system. However, there is cause for optimism: in some other European countries, nitrate concentrations are now falling in rivers thanks to actions taken to reduce farm pollution.

> **"There are more than 20 million farmed birds in the Wye catchment"**

Cattle manure is among the biggest polluters of UK rivers

SEBASTIAN WASEK/LOOP IMAGES LTD/ALAMY

Enforcement is all very well, but to tackle this huge issue, farmers also need to be on board. Most say that, with the right support and technology, their contribution to water pollution can be dramatically reduced.

I see this for myself on a dairy farm in Cornwall. When Katie and Andrew Hoare took over the tenancy of Trenance Farm, the existing slurry pit wasn't fit for purpose. "It was all full and it was overflowing," says Katie. "But we had to keep putting shit in because we had nowhere else to put it."

However, in 2021, their landlord, Cornwall Council, working with renewable energy firm Bennamann, installed a state-of-the-art methane-capturing slurry pit. It provides the farm with six to eight months of slurry storage along with a constant supply of methane, which is used to power a tractor. "It's just like a normal tractor," says Hoare, showing me around the gleaming blue machine. "But when the fuel light comes on, you just drive it down to the pit, plug it in and fill it up." This is as green as slurry management gets, but it doesn't come cheap. The Hoares's methane-capturing slurry pit is one of six planned as part of a £1.58 million pilot project, funded using a green energy grant from the EU. That puts the cost of each at more than £250,000.

Of course, the dairy industry isn't the only major source of agricultural pollution in British rivers. A growing taste for chicken – which now accounts for more than half of the UK's meat consumption – has led to an explosion in the number of intensive poultry units. Many of these are clustered along the banks of the river Wye, which runs through Wales and then along its border with England to the Severn estuary. Two decades ago, there were just 60 intensive poultry sheds

SAVE BRITAIN'S RIVERS

DAVID STOCK

Intensive agriculture has had big impacts on the Teifi marshes

in the English counties of Herefordshire and Shropshire. By 2020, that had increased to more than 1150, according to the Food, Farming and Countryside Commission. Campaigners estimate there are now more than 20 million farmed birds in the Wye catchment and say the river is overloaded with phosphorus from poultry manure, leading to devastating algal blooms.

A proliferation of turkey and chicken production is harming the river Wye

MH FOOD/ALAMY

Pesticide contamination is also a growing issue. Campaign group WildFish conducts a regular "Riverfly Census", covering 12 rivers, and its data suggests pesticide runoff from farms is destroying invertebrate populations. The most recent survey indicated a sharp jump in chemical stress on these communities, with the number of species of mayflies, stoneflies and caddisflies all declining since 2015.

When pesticides enter waterways, it isn't just wildlife that suffers. Even relatively small amounts can be enough to breach strict drinking water standards. As a result, water companies face having to spend millions on additional treatment technology at their plants. This, however, can provide an incentive to tackle the problem at source. As utilities firm Welsh Water discovered a few years ago, such an approach can have additional benefits.

In 2013, water quality tests at several of Welsh Water's treatment works started to show increased levels of a herbicide called MCPA. At first, officials were stumped as to the cause. They asked local councils if they had started using more MCPA on their land; caravan site owners were also questioned. Eventually, it transpired that farmers had turned to MCPA in their droves following the wettest summer in Wales in 80 years in 2012, which had resulted in rushes spreading across their fields, says Sarah Jones at Welsh Water. "It was having an impact on their grazing, on their forage land."

So the company decided to try to help farmers change their ways. In 2015, it launched the Weed Wiper project across the river Teifi, Wye and Towy catchments. Farmers were offered the free hire of a weed wiper, a piece of farming equipment allowing them to target specific weeds with pesticide rather than blanket spraying an entire area. Over the next three years, almost 300 weed wiper hires were logged and accompanying information about best practice when it comes to using pesticides was handed out to farmers. Subsequent analysis by researchers at the University of Leeds, UK, and their colleagues found that MCPA levels in waterways dropped by 45 per cent across the catchments, compared with a 10 per cent fall in control catchments. On the Teifi, where the majority of weed wipers were hired, MCPA concentrations fell by 55 per cent. "But it wasn't just about the number of hires," says Jones, who led the project. "It was about the conversations we started with farmers and the behaviour change it was starting to generate."

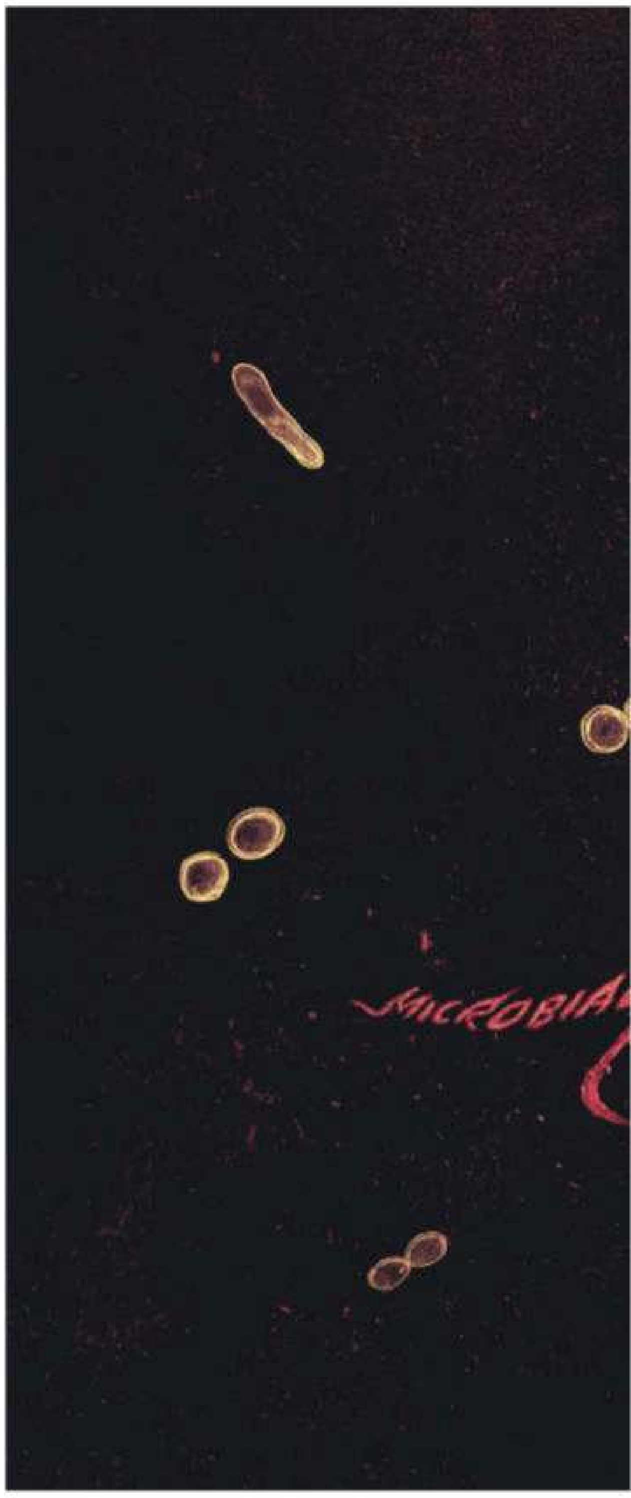
Such projects give hope that farmers can be nudged in the right direction. Nevertheless, the rapacious demands of the global food system make it increasingly challenging for farming to be environmentally friendly. The scale of the problem has left some conservationists believing that the only solution is to overhaul the sector. "A lot of farms are getting bigger and bigger," says Nathan Walton, who works for the Wildlife Trust of South and West Wales managing the Teifi Marshes Nature Reserve. This site has been badly affected by intensive farming practices in the past decade. "As a conservationist, I would love to revert back to the old practices, where you had smaller farms, small fields, managed less intensively and more sustainably."

Walton acknowledges that such reform isn't just down to farmers. We all need to get behind it and make some tough decisions. "The only way things are going to change," he says, "is if we, as a society, learn to pay a bit more for our food and give farmers a better return for what they are producing." ▮

Madeleine Cuff is a news reporter at *New Scientist*

Bugging cancer

Microbes have a natural affinity for tumours, opening up incredible new ways to fight cancer, discovers **Alice Klein**



PETER STRAIN

SALMONELLA bacteria are normally associated with violent food poisoning. But in 2019, Irit Balboul, a 71-year-old Canadian, volunteered to drink a liquid containing 1 billion live *Salmonella typhimurium* bacteria as a last resort against her pancreatic cancer, which had spread to other organs and given her just months to live.

The bacteria had been genetically engineered to trigger an immune attack on her cancer cells, while being less toxic than regular *Salmonella* to the rest of her body. Balboul was the first person in the world to trial them along with chemotherapy and her tumours shrank to just 10 per cent of their former size.

It may sound strange to use bacteria to treat cancer, but the approach harks back to the late 1800s, when William Coley, a New York surgeon, began injecting *Streptococcus* bacteria into the inoperable tumours of some of his patients, resulting in regressions he described as "nothing short of marvellous". Despite this promise, the approach fell out of favour. More than a century later, however, we are witnessing Coley's comeback.

It is now clear that many bacteria are naturally attracted to tumours, which are home to a rich microbial ecosystem. This tumour microbiome can influence how cancer progresses and responds to treatment. A clearer appreciation of this system is leading to the development of new microbial medicines targeting cancer, some of which are now in clinical trials – including the engineered *Salmonella*. These microbes can burrow deep into places that are hard to reach with existing treatments such as chemotherapy and can be equipped with extra, cancer-fighting weapons through genetic engineering, offering alternative ways to attack tumours.

Most people are now familiar with the gut microbiome – the complex community of bacteria, fungi, viruses and other microbes that inhabit our guts and influence our health in myriad ways. But the idea that tumours are also teeming with microbes only came to the fore in 2020, when Ilana Livyatan at the Weizmann Institute of Science in Israel and her colleagues analysed bacteria in more than 1000 human tumour samples.

Using genetic sequencing, they identified bacteria in all eight tumour types they studied: breast, brain, lung, skin, bone, ovary, pancreas and colon. "It made us raise our eyebrows and say, 'Hey, what are they doing there?'," says Livyatan. On average, they found roughly one bacterial cell for every 150 tumour cells, but some tumour types, such as those of the colon and breast, typically harboured more bacteria than others. Even more surprising was the discovery that each tumour type had its own distinct microbial signature.

Last year, Livyatan and her colleagues dropped another bombshell: they had found fungi in tumours too, in all eight types that had previously tested positive for bacteria. At the same time, a team led by Iliyan Iliev at Cornell University in New York revealed that it had also sequenced fungal DNA in a range of tumours. These included *Candida* fungi – which are more commonly associated with vaginal and oral thrush – in cancers of the stomach, colon, head and neck (though the amounts were tiny: about one fungal cell per 10,000 tumour cells). "It was kind of mind-blowing," says Iliev. "Something seems to be attracting the fungi to some tumours because when we look at tumour tissue and the adjacent tissue from the same patient, we see that the fungal cells are preferentially abundant in the tumour," he says.

There are many reasons why microbes might be attracted to tumours (see "Ideal home for bacteria", page 42), but what is becoming clear is that their presence can influence the course of cancer and its treatment.

Bacteria called *Fusobacterium nucleatum*, for example, can promote colon cancer, accompany its spread to other parts of the body and dampen its response to chemotherapy. These bacteria mostly live in the mouth, but can invade the bloodstream and then circulate to the colon. There, they can colonise polyps – clumps of cells that form on the lining of the colon – and turn them cancerous. Similarly, the presence of *Malassezia globosa* fungi in breast tumours, which are thought to travel there via ducts connecting the skin and breast, has been associated with poorer survival rates.

We have also known for decades that

certain viruses can trigger cancer formation: for instance, human papillomavirus (HPV) and hepatitis B virus (HBV), which are associated with cancers of the cervix and liver respectively. HPV inserts its DNA into the genomes of healthy cervical cells and causes them to grow out of control, becoming cancerous, and we are now getting a clearer picture of the mechanisms by which other microbes can influence the progression of cancer (see "Microbial manipulations", page 43).

Vaccine hope

Fortunately, we now have HPV and HBV vaccines to help prevent their associated cancers. In the same way, we may be able to develop vaccines against tumour-promoting bacteria, says Robert Holt at the British Columbia Cancer Research Institute in Canada. These have the potential to inhibit the growth of bacteria in existing tumours, slowing their progression and making them more responsive to chemotherapy. They could even stop tumours from forming in the first place.

Holt and his team are specifically working on a vaccine against *F. nucleatum*. The vaccine contains messenger RNA (mRNA) that is designed to instruct the body to make certain protein fragments found in this bacterium. The idea is to train the immune system to recognise and kill the microbe. At this stage, the vaccine is still being tested in mice, but Holt and his colleagues hope to one day trial it in people with *F. nucleatum*-positive colon cancer that is resistant to conventional treatments.

Taking "bad" microbes out of tumours is one strategy to tackle cancer, but another may be to send in "good" microbes. This is the approach that Coley took, inspired by reading about a man whose large neck tumour disappeared after he developed a *Streptococcus pyogenes* infection at the site where his surgeon had unsuccessfully tried to cut the tumour out.

When Coley injected live *S. pyogenes* into 10 of his patients' tumours, half had partial or complete tumour regressions. However, he found it difficult to get the dose right and some of his later patients died from the treatment. The turn of the 20th century saw the arrival of radiation therapy, which was seen as safer, and Coley's approach fell by the wayside.

We still aren't sure how Coley's treatment worked. It is most likely that the *Streptococcus* bacteria he injected into his patients' tumours made them more visible to their immune systems, says Livyatan. Although small

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New Scientist Live
Do tumours have an electrome as well as a biome?
Sally Adee reveals the extraordinary power of bioelectricity at New Scientist Live **newscientistlive.com**

> **“The tumour shrinkage was striking. None of us had seen anything quite like it before”**

amounts of bacteria can hide in tumours because of cancer’s immune-evading mechanisms, injecting large doses of them into tumours may be enough to trigger alarm bells so that the immune system launches an assault on the cancer cells that the bacteria are living in, she says.

Research by another group at the Weizmann Institute of Science led by Yardena Samuels has provided some clues as to how Coley’s bacteria may have made tumours more visible to the immune system. The team discovered that protein fragments from bacteria that colonise melanoma skin cancers are expressed on the surface of the cancer cells. These signpost the tumour as foreign to the immune system, so that it realises “Hey, something’s wrong here” and attacks the cancer cells, says Livyatan.

The *Salmonella* that were used to treat Balboul had been genetically engineered to rev this mechanism up even further. They were made to express a protein called interleukin-2 that activates the immune system. “The *Salmonella* goes directly to the tumour and it brings along the interleukin-2 so that the whole body’s not exposed to the interleukin-2, just the tumour,” says Gerald Batist, the oncologist who oversaw Balboul’s treatment at the Jewish General Hospital in Montreal. “It creates an immune activity against the tumour right at the site of the tumour.”

Living longer

Balboul trialled the treatment alongside standard chemotherapy. The dramatic shrinkage of her tumours was a far stronger response than would be expected with chemotherapy alone. “It was very striking – none of us had seen anything quite like it before,” says Batist. What’s more, the bacteria didn’t make her sick, he says. “The idea that we would have someone drinking bacteria really freaked out the infectious disease people on our ethics committee, but she had no side effects whatsoever.”

After Balboul’s promising response to these bacteria, Batist and his colleagues launched a phase II clinical trial in 2020 involving 20 people with stage 4 metastatic pancreatic cancer – considered one of the worst of the worst cancers. The trial participants were all treated with standard chemotherapy plus the engineered *Salmonella*. The results, which were released in January, showed that the participants lived for 24 months on average, which is more than double the typical survival length of 11 months for standard chemotherapy alone. The *Salmonella* didn’t make these volunteers sick either.

“It’s not a miracle cure, but a doubling of survival is quite significant if we can confirm it in larger trials,” says Batist. A major advantage of this approach is that bacteria are far cheaper to manufacture than other cancer immunotherapies like checkpoint inhibitors, CAR T-cell therapies and personalised vaccines, he says. The US Food and Drug Administration (FDA) recently gave the *Salmonella* therapy fast-track status to make it available as soon as possible if it passes future trials. And last year, a study in mice showed that tumour-homing bacteria could be controlled by ultrasound to release cancer-fighting substances, offering a potential new route to precise targeting.

A company in Switzerland called T3 Pharma is also using bacteria to try to supercharge the immune system against cancer. It is mainly working with a bacterium called *Yersinia enterocolitica*, which is a contaminant of pork that can cause food poisoning, but has been genetically engineered to “down-tune its virulence”, says Christoph Kasper, the firm’s chief scientific officer.

An extra bonus of *Y. enterocolitica* is that it has special “nano-syringes” on its surface that it uses to inject proteins into cells. T3 Pharma has engineered a strain of *Y. enterocolitica* that can inject proteins into tumour cells to make them release signalling molecules that “act like warning signals to bring the immune system into play to fight the tumour”, says Kasper.

When the engineered *Y. enterocolitica* were injected into the blood of mice with melanoma or other tumours, they selectively homed in on the tumours and caused them to disappear in up to two-thirds of the animals, with no serious observable side effects. The company has just launched a clinical trial of the engineered *Y. enterocolitica* in people with solid tumours. “We’re very excited,” says Kasper.

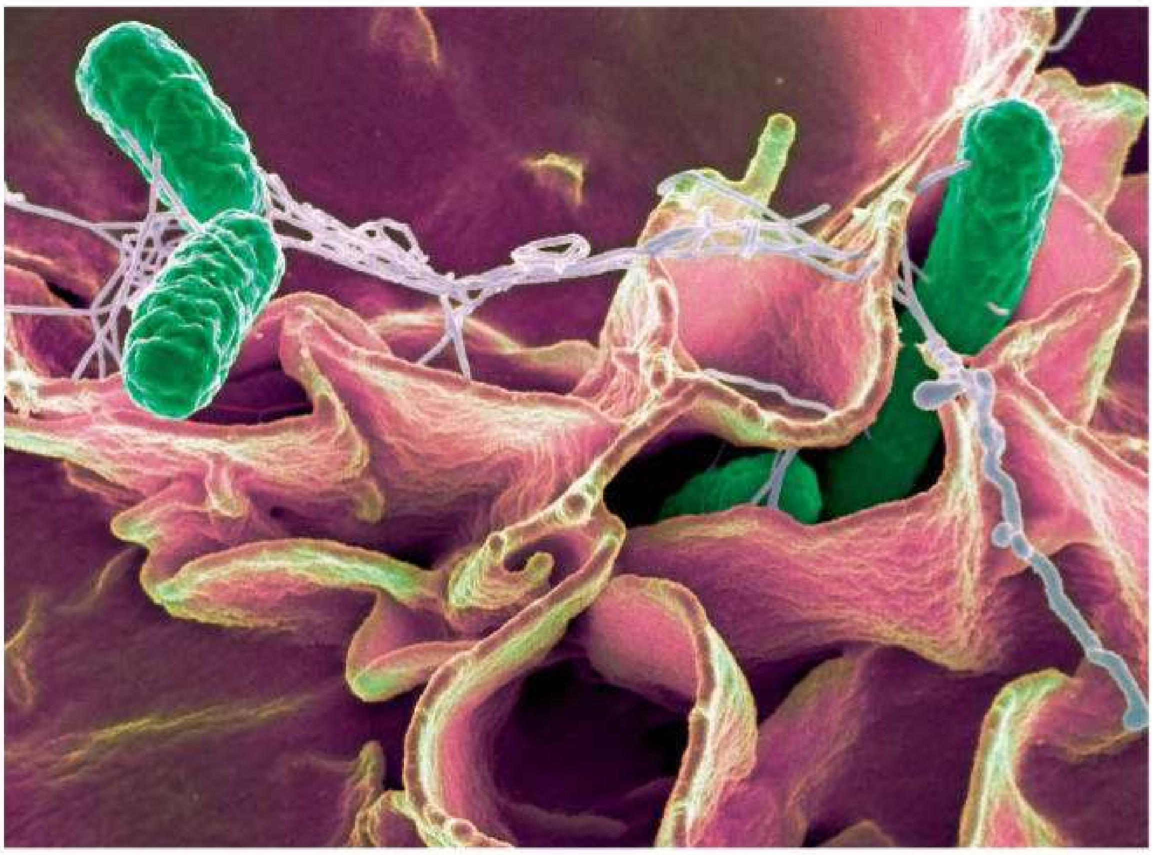
BioMed Valley Discoveries, a company based in Missouri, is pursuing a different approach to target the low-oxygen pockets inside tumours that are often resistant to existing cancer treatments. It is injecting spores of anaerobic *Clostridium novyi* bacteria, which have been genetically modified to make them less toxic, directly into solid tumours. The spores only germinate in the low-oxygen regions of tumours and, as they proliferate, they alert the

Ideal home for bacteria

The reason certain bacteria are attracted to tumours is still an open question, says Ilana Livyatan at the Weizmann Institute of Science in Israel. “If you grow a tumour in a mouse and then inject bacteria into its bloodstream, the bacteria will home to the tumour, but we don’t really know why yet.”

One suggestion is that blood vessels in tumours grow in a fast, chaotic way, forming twists and dead ends that may trap bacteria. Another is that the rapid metabolism of tumours provides abundant nutrients for bacteria to feed on. Low-oxygen pockets that typically form inside tumours may also attract oxygen-hating bacteria called anaerobes. And tumours often develop ways to evade detection from the immune system, making them perfect hiding spots for microbes.

Certain tumours provide the right kind of food for particular microbes. Lung tumours of smokers, for instance, seem to favour the growth of bacteria that can degrade components of cigarette smoke such as nicotine.



NIAID/CDC/SCIENCE PHOTO LIBRARY

FG TRADE/GETTY IMAGES

Above: Bacteria such as *Salmonella* (green) can be weaponised to fight cancer. Left: Vaccines against tumour-promoting bacteria are in development

Microbial manipulations

We know that microbes can cause cancer or influence tumour growth, but how exactly do they do this?

Some bacteria, like *Escherichia coli* (*E. coli*) and *Campylobacter jejuni*, release toxins that directly damage the DNA of human cells, turning them cancerous. And microbes that make their homes in already-established tumours can also help them to expand. For example, certain tumour-dwelling bacteria release chemicals that suppress the activity of nearby immune cells, making it easier for the cancer to grow unchecked.

When bacteria are inside tumour cells, they can also reshape the cells' cytoskeletons – the structures that maintain their shapes – to make them stronger. This allows the cells to resist damage while travelling through the body and seeding new tumours. In contrast, some bacteria seem to dampen tumour progression. For instance, *Helicobacter hepaticus* has been shown to shrink colorectal tumours in mice, most likely by attracting nearby immune cells.

immune system to start attacking these areas.

In a first-in-humans trial published in 2021, the bacteria were injected directly into the tumours of 24 people. There, they were found to essentially liquefy the tumour's low-oxygen innards. "You still had a ring of tumour cells on the outside, where the tumours were well-oxygenated and the bacteria couldn't grow, but in the middle, it was just fluid and gas where the cells had been destroyed," says Brent Kreider, president of BioMed Valley Discoveries.

The *Clostridium* bacteria are now being evaluated in a second clinical trial, this time in combination with the checkpoint inhibitor pembrolizumab – more commonly known as Keytruda – that can target the outer tumour cells. "The idea is for the bacteria to fight the tumour from the inside out and the pembrolizumab [to fight it] from the outside in," says Kreider. The results will be made available later this year, he says.

Bacteria aren't the only microbes getting attention, however. Several tumour-fighting viruses are also under investigation. One of these, called T-VEC, was approved by the FDA in 2015 for treating melanoma that had spread to other parts of the body. T-VEC uses a strain of herpes simplex virus 1, which normally causes cold sores, but has been genetically engineered to make it less harmful to healthy tissue and to invite an immune attack when it is inside tumours.

These are some of the most promising stories, but there have also been disappointments in the field. A trial of genetically engineered *Listeria* bacteria in people with lung cancer, for instance, was discontinued in 2018 after it was found to be ineffective, and another of genetically engineered *Bifidobacterium* in people with a range of tumour types was terminated in 2021 for the same reason.

"It's still a young field and it's not a classical way to approach cancer intervention – you're injecting something live, it's not like a pill – so there is still a lot to learn and it can be a bit of a struggle," says Kreider. "But I think there is great hope."

As for Balboul, after being told she only had months to live, she ended up living over three more years until recently passing away at the age of 74. "Her cancer came back and she decided she didn't want further treatment," says Batist. "But when I told her that we were able to get a phase II trial started [of the *Salmonella* bacteria], she was extremely excited," he says. Thanks to her courage in trialling the unusual treatment, Coley's once-shelved approach may finally find a place in modern medicine. ▮

Alice Klein is a reporter for *New Scientist*

Puzzles
Try our crossword, quick quiz and logic puzzle p45

***Almost* the last word**
If people colonised Mars, how would they tell the time? p46

Tom Gauld for *New Scientist*
A cartoonist's take on the world p47

Feedback
Not-so-comforting comfort food and missing missiles p48

Twisteddoodles for *New Scientist*
Picturing the lighter side of life p48

The science of cooking

Endless pastabilities

You don't need eggs and special gadgets to make pasta at home – semolina, water and a good knead will do it, says **Sam Wong**

Sam Wong is assistant news editor and self-appointed chief gourmand at *New Scientist*. Follow him @samwong1

What you need

For 2 servings:
250 grams or
1⅓ cups semolina
125 millilitres or
½ cup warm water

The science of cooking appears monthly. Share your cooking successes with us on Twitter and Instagram @newscientist, using the hashtag #NewScientistCooking

Next week

60-second psychology

IF YOU see someone making pasta on a cooking show, they are usually mixing white flour with egg yolks, then rolling the dough out thinly with a machine. This is one way to do it, but most pasta isn't made from flour and eggs – and you don't need any special gadgets to make it.

ANDREAGABRIELLI/SHUTTERSTOCK

Most Italian pasta is made from a different wheat to the kind ordinary flour comes from. Called durum wheat (*Triticum durum*), it thrives in drier regions like southern Italy, and it gets its name from the Latin word for hard. The kernels appear glass-like, or vitreous, and when milled they tend to fracture into pieces, rather than becoming fine particles like flour. This produces semolina, which has a sand-like coarse texture. It gets its yellow colour from carotenoid pigments.

The coarseness of semolina has some advantages for making pasta. When grains are finely milled, the starch granules get cracked. This is good for bread-baking, since enzymes can more easily break the starch down into simple sugars that yeast can ferment. But when you make pasta from finely milled flour, more of the starch leaks out during cooking, making the pasta sticky. The cracked starch granules in flour also absorb more water, which isn't ideal if you're making dried pasta, since it means more energy is needed to dehydrate it.

When pasta is made from white flour, egg is usually added to the dough. This provides colour and richness, as well as extra protein, which makes the dough more cohesive and helps keep the starch in during cooking. Egg makes the pasta more perishable, so this is mainly used for fresh pasta.

Durum wheat has a high protein content, which means the pasta keeps its shape well when cooked and has a good bite to it. But it is harder to roll thin, so egg and flour tend to be used for filled pasta.

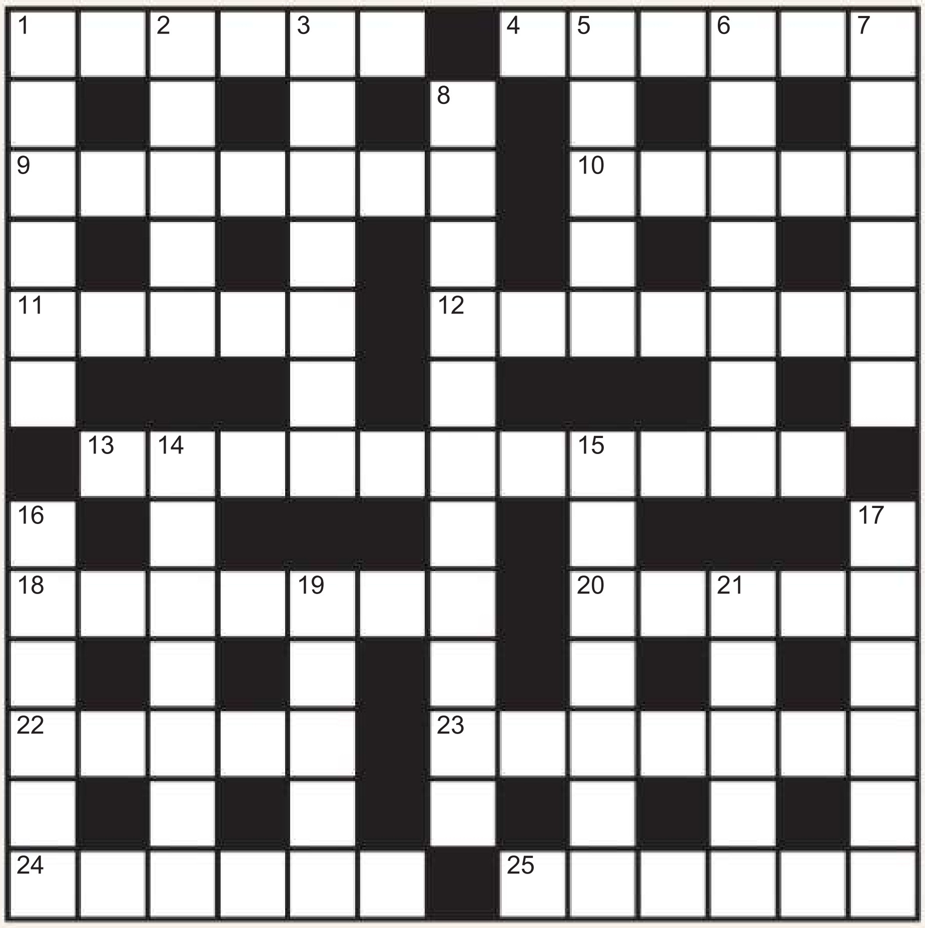
Orecchiette, or "little ears" (pictured), are a type of pasta made from semolina in Puglia, Italy. To make the dough, add the water to the semolina in a bowl and mix with a fork. Once combined, tip onto a work surface and knead the dough for about 8 minutes, until it is smooth, elastic and not sticky. Cover with a towel and let it rest for about 30 minutes.

Then, cut off a piece of dough and roll it into a cylinder, 1.5 centimetres thick. Cut this into pieces 1 centimetre wide. Drag a butter knife across each piece, pulling towards you to stretch it thin, then turn it inside out – it may help to watch a video to learn this technique. Place the pieces on a tray sprinkled with semolina, so they don't stick together. Leave them to dry slightly, for at least an hour. Then they are ready to cook, or they can be left to dry more fully for a day or two.

Cook in salted water for 6 minutes or longer, depending on how long they were left to dry. When the pasta is cooked to your liking, drain and mix with sauce. ■

These articles are posted each week at newscientist.com/maker

Cryptic crossword #112 *Set by Wingding*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Metal coating of church, somewhere in Italy (6)
4 Some flipping hooligan is crashing function (6)
9 Spaceship transported ovary with half of eggs (7)
10 African people outlaw workers' group (5)
11 Spectrum of emotion, back to front (5)
12 Fragrant plant's soft material is initially gathered by Goodall (7)
13 EU ban on oil designed to cover Russia, where stars are born (5,6)
18 Dance around the Spanish fruit (7)
20 Food pipe meets resistance (5)
22 Carnivore's class includes lightweight (5)
23 Dog made soy sauce (7)
24 Trick to cause annoyance with swollen shape (6)
25 Eat for laughs, they say (6)

DOWN

1 Hidden shroud on top of tree (6)
2 Bit of light above fabric (5)
3 Tango with me, fixing generator (7)
5 Picture puzzle on public transport (5)
6 Uni lads reconstructed ancient instrument (7)
7 Feeling sick in sauna? Use antiemetic (6)
8 Malware breaks Jon's heart outside surgery (6,5)
14 German physicist is right on time and oddly green (7)
15 Pitch had painful effect on university fellows (7)
16 Figure in charge not going anywhere (6)
17 King to revise amount of money in bank (6)
19 Spooky-sounding nest (5)
21 Child starts to like eminent chemist (5)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #207
set by Bethan Ackerley

1 In what year was the US space station Skylab launched?

2 Antoine-Laurent de Lavoisier named which two elements?

3 Diphyodont animals develop two full sets of what?

4 In oceanography, what is a large system of circulating ocean currents called?

5 The compound formed during anaerobic respiration with the formula $C_3H_6O_3$ is better known by what name?

Answers on page 47

Headscratcher
set by Brian Hobbs
#227 A great deal of magic

"Can I have a volunteer?" Max the Magnificent asks his handful of onlookers.

A hand goes up. "Good!" he exclaims. "You there, madam. I will now blindfold myself and hand you this ordinary deck of 52 cards. I would like you to flip over exactly 26 of the cards and return them to the deck, then shuffle thoroughly."

When the deck is returned, Max appears to feel, tap and listen to the cards, then cuts them into three piles before restacking them. "And now, miss," he says. "Would you please shuffle once more and deal out the cards into a pile for you and a pile for me?"

When she does this, Max flips over his pile and sure enough, as the two hands are examined, they each have exactly the same number of face-up cards.

"Impressive," whispers Marcus.

"He's certainly a good showman," replies Nina. "But you and I could have pulled off that 'trick' with little difficulty."

No sleight of hand or other hidden trickery was involved, so how did Max accomplish his feat?

Solution next week

Too much time

If humans colonised Mars, how would they calculate time, as a Martian day is longer than one on Earth?

Bob McCrossin
Cooroy, Queensland, Australia
It is more complicated than you might think, if you don't have a clock.

There are three kinds of day to consider. The sidereal day is the planet's rotation period to come back to the same position compared to the fixed stars. The solar day is the period for the sun to come back to the same spot in the sky. It is a bit longer than the sidereal day because the planet has advanced in its orbit around the sun and the elliptical orbit makes the "same spot" not quite so.

The astronomical times to the nearest minute are: Earth sidereal 23 hours 56 minutes, solar 24h; Mars sidereal 24h 37m, solar 24h 40m.

Finally the human diurnal (daily) rhythm is the time the body "thinks" it has done a day's worth of metabolising and restarts. The body adjusts to the solar day by referencing the sun. Humans with no light perception have an average "daily" rhythm of about 24h 28m, so we are actually slightly better adapted to Mars.

"Time, be it on Mars or Earth, is a human construct used to help us organise and regulate many aspects of life"

The Martian hour would need adjusting, but an alternative would be to retain Earth hours and follow the Roman tradition of the Saturnalia used to line up the lunar and solar years. This would mean 40 minutes of party time at the end of each Martian day.

There is, of course, a theory we actually came from Mars, or at least that is where early microbial life may have come from. But who knows? Maybe we originated on the planet Golgafrincham.

Alex McDowell
London, UK
In the books *Martian Time-Slip* (1964) by Philip K. Dick and *Mars Trilogy* (1992-96) by Kim Stanley Robinson, Mars settlers use clocks like those on Earth, except that, at midnight, the clocks stop for 39 minutes and 35 seconds (the extra length of a Martian solar day) and then start again.

Since the Viking craft reached the planet in 1976, Mars landers have used clocks that divide a Mars day, or sol, into 24 "Martian hours". Planetary scientists define the Martian new year as starting on its vernal equinox and have defined a Mars calendar.

Mars colonists may be more radical and use a Martian decimal time system, in other words, divide the Martian day into 10 hours and the hours into 100 minutes.

Stephen Johnson
Eugene, Oregon, US
Time, be it on Mars or Earth, is a human construct used to help us organise and regulate many aspects of life.

Originally, humans divided the day into two parts, day and night. Later, with the invention of sundials and primitive clocks, we started to divide the day into smaller units. The 24-hour day came from the Egyptians along with the sexagesimal number system they used, with a base of 60. This system, previously used by the Babylonians, divided both the circle and the year into 360 segments. Our use of 24 hours, 60 minutes in an hour and 60 seconds in a minute all come to us from this system.

The important point is that time wasn't a fixed interval, but an arbitrary one based on dividing the day into 24 parts. On Mars, the easiest way to tell time is to use the exact system of hours, minutes and seconds that we use on Earth, but to make each second 2.75 per cent longer to account for the extra time in a Martian day. This is the convention all craft that landed there to date have used. No doubt for some science on Mars, a form of radioactive decay, or crystal vibration frequency, will be used to ensure identical intervals to those used on Earth when making measurements.

Pat French
Telford, Shropshire, UK
The New Martians will quickly establish their own routines. The difference in day length compared with Earth is only about 40 minutes. They could choose any subdivision of a Martian day that they liked to replace hours.

The Martian year is almost twice as long as Earth's and a Mars calendar is likely be independent. A phone application could simply convert months to Phobosths (Phobos moon cycles) in much the same way that today's conversion tables convert kilometres to miles and vice versa. Birthdays will be a long way apart on Mars, 687 Earth days to be precise.

There are some very precise chronometers involved in satellite navigation and in the calculation of flight paths, trajectories and orbiting speeds. This requires calculations involving the speed of light. For these purposes, there needs to be a precise standard time system. It is probable that the current system will continue to be used, at least until the time of Martian independence comes.

JUHKU/SHUTTERSTOCK

Cats devote many hours to washing themselves, so why don't dogs?

This week's new questions

Dirty mutts **Why do cats wash themselves, while dogs don't?** ***Richard Grimmer**, Trowbridge, Wiltshire, UK*

Solid ground **If 21st-century babies are weaned on a globalised diet that has only recently been available, what was used to wean babies in prehistoric times?** ***Ian, Naraa and baby Vaughan Allardyce**, London, UK*

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Tom Gauld
for New Scientist

THE NANOTECH TEAM IS HERE. SHALL I SEND THEM IN?

Rob Walker
via Facebook
We would divide the 24.6 hours of a Mars day into three equal bits. One for work, the second for rest and, finally, a period of play. Because, as we all know, a Mars day helps you work, rest and play!

Cool melt

In Spain recently, in temperatures around 34°C, the ice cubes in my drink took far longer to melt compared with at home, where it is much colder. Why the difference?

Guy Cox
Sydney, Australia
The rate at which ice cubes melt depends on the temperature of the drink, not the ambient temperature. In my experience, Spanish cafes and bars keep their drinks very cold, which obviously makes sense when it is 34°C (93°F).

In England, on the other hand, drinks and mixers are often not refrigerated at all and just rely on ice cubes to cool them. No wonder the ice melts faster.

> "Unlike in Spain, in England, drinks and mixers are often not refrigerated at all, so no wonder ice in them melts faster"

David Bortin
Whittier, California, US
We all know, of course, that the rain in Spain falls mainly on the plain – where it dissolves a lot of minerals, resulting in "hard water" coming to Spain's taps. Does hard water make hard ice?

But seriously, the questioner's observation isn't from a well-controlled experiment; there are too many unspecified variables.

Ice forms from water at around 0°C (32°F), but that doesn't mean that ice cubes are necessarily stored at that temperature; they are usually colder by amounts that can vary widely. The other ingredients in the drink, even if they turn out to be chemically identical in the UK and Spain, may well have been refrigerated at different temperatures.

There is often little correlation between the outdoor temperature reported in the news and the (usually indoor) air temperature where beverages are commonly consumed. Ice "cubes" are a non-standardised commodity that vary widely in size and shape; melting is a process that depends on the ratio of surface area to mass.

Drink recipes are likewise non-standardised. In fact, it is to be expected that the ice-to-liquid ratio would be positively correlated to the local air temperature at the time of preparation.

Cups and glassware, as well, can influence the heat exchange rate. Composition, insulation, capacity, shape and mass are among the factors that would need to be controlled.

Finally, "far longer" is an unquantified and highly subjective measure of elapsed time, perhaps even more so when considering any holiday-related alcohol and relaxed mood. ▮

Answers

Quick quiz #207
Answers

1 1973
2 Oxygen and hydrogen
3 Teeth
4 A gyre
5 Lactic acid

Quick crossword #135 *Answers*

ACROSS 9 Optical illusion, **10** Elm bark, **12** Manatee, **13** Parkinson, **14** Yeast, **15** Cascade, **18** Oilseed, **21** Bleed, **23** Numerator, **25** Element, **26** Lobster, **29** Anorexia nervosa

DOWN 1 Mole, **2** Atom, **3** Sciatica, **4** Flukes, **5** Flamingo, **6** Quinsy, **7** Filtrate, **8** Untested, **11** Llama, **15** Cable car, **16** Skeleton, **17** Einstein, **19** Lyrebird, **20** Erode, **22** Diesel, **24** Melons, **27** Tool, **28** Road

#226 On reflection
Solution

The text reads: A MAN A PLAN A CANAL PANAMA.

The string of letters is the same forwards and backwards, so it must encode a palindromic set of words. The majority of the letters are X, which suggests X is probably a vowel or very common consonant, such as T. If the first space comes after the first letter, the first word can only be A or I. If it is A it would be as follows: A *A*A**A*A*A*A**A*A*A. Not many words have alternate As. Some examples are llama, lava or longer words such as banana… and Panama. Panama reverses to make "A man a p" and leads to the classic palindrome: A man a plan a canal Panama. (Other palindromes you can spot within the puzzle are Hannah, wow and aha.)

Not such a comfort

To see how a man's stress levels and diet might alter his shape, one might give comfort food to a stressed rat and study its penis.

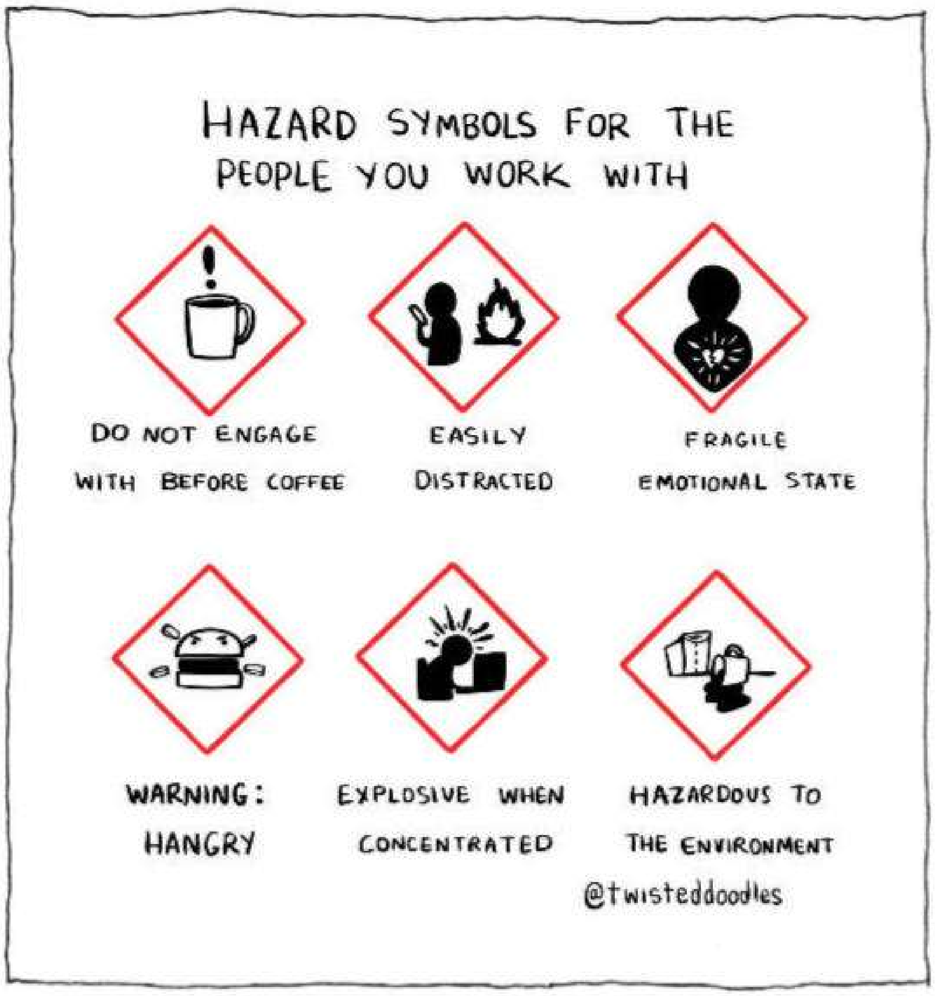
Researchers at the State University of Rio de Janeiro in Brazil did exactly that, but with a larger number of rats (32 in total, though not all were given comfort food and only some were stressed). The team published an account in the journal *Heliyon*, with the title "Effects of comfort food diet on the penile morphology of stressed rats". Javier Segura brought it to Feedback's attention.

This experiment qualifies as fruitloopery. The paper says: "Froot loops was used as comfort food due to its nutritional components which are listed in Table 1."

Many humans love Froot Loops and have a penis, so why experiment with rats, rather than humans? One reason may be the painstaking way in which measurements were taken after eight weeks of Froot Loops: "The penises were collected and their skin-denuded middle shafts were fixed in a 4% buffered formaldehyde solution."

After doing some penis-gazing, the researchers say, "Chronic stress caused important structural damage to the penis which may be related to erectile dysfunction." Also, they say, "The consumption of comfort food aggravated penile damage caused by chronic stress and should be avoided during stressful situations."

Twisteddoodles *for New Scientist*


HAZARD SYMBOLS FOR THE PEOPLE YOU WORK WITH
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Consideration of items sent in the post will be delayed

Somewhat missing stuff

Feedback hinted a few months ago that a Global Registry of Missing Stuff, if such a thing existed and were accurate, would include six US nuclear bomb cores and most of the mass that constitutes the universe (8 February).

Things continue to go missing in our universe, leading to puzzlement. Or professed puzzlement. Occasionally an object, having been noticed, becomes Officially Not Noticed by High Officials. A recent example cropped up and down in Poland.

Polish military and political officials are facing questions, the Associated Press has reported, about an "object that landed on Polish territory in December, but which was only discovered in April by chance by a member of the public who was riding a horse in a forest".

A Polish journalist tells Feedback that during those four months from December to April, everyone was aware that the object was somewhere in Poland, but the government apparently made no effort to find it or acknowledge its existence. The journalist says, "It was probably a missile sent into Poland by mistake in a typical Russian army screw-up. It was unarmed." The horseback rider's discovery forced the government to officially stop not noticing the object's existence.

The Associated Press reports that the Gdansk prosecutor's office "said it would not comment on theories appearing in the Polish media about where the item came from and that it was exploring several threads".

Unskilled and unaware

The long tango continues between two groups of researchers who try to understand why people behave in doggedly human ways.

One group, psychologists, sometimes tries to use mathematical tools to analyse human behaviour that can be difficult, maybe impossible, to analyse using only mathematical tools. The other group, mathematicians, also sometimes tries to use mathematical tools to analyse human behaviour that can be difficult, maybe impossible, to analyse using only mathematical tools. Each group tends to see itself as more competent than the other at analysing human behaviour.

Enter, stage left, the Dunning-Kruger effect. In 1999, psychologists David Dunning and Justin Kruger at Cornell University in Ithaca, New York, published a study called "Unskilled and unaware of it: How difficulties in recognizing one's own incompetence lead to inflated self-assessments". Subsequently, the phrase "the Dunning-Kruger effect" became famous – appearing in more than 5000 academic papers, and also delighting much of the general public.

In 2017, Eric Gaze at Bowdoin College in Maine, together with colleagues, published a paper that, the team says, "subverted behavioral scientists' explanations" of the Dunning-Kruger effect.

Gaze has now doubled down on his mathematical pooh-poohing of the Dunning-Kruger effect, via an essay in *The Conversation* called "Debunking the Dunning-Kruger effect – the least skilled people know how much they don't know, but everyone thinks they are better than average".

Near the end of the essay, Gaze says: "But according to the work of my colleagues and me, the reality is that very few people are truly unskilled and unaware."

Feedback lacks the skill to calculate the degree of self-confidence behind that statement.

Distance learning

Having surveyed Feedback's list of trivial superpowers, Mandi Brooker adds one that is educational. She says: "I am a high school maths teacher with absolutely no sporting/throwing/kicking ability whatsoever, but when I find that a whiteboard marker is getting irritatingly faint, I can hurl it right across a big classroom unerringly into the bin, every time. It impresses the kids no end, which is all there is to teaching, really". ■

Marc Abrahams

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New Scientist Jobs and Metro.co.uk are conducting a survey to understand the experience of the global LGBTQIA+ community in STEM.

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